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THE GEOLOGY OF THE

HIGHWOOD-ELBOW AREA

ALBERTA

J. L. CARR

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THE GEOLOGY OF THE HIGHWOOD-ELBOW AREA, ALBERTA

by

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requirements for the degree
of
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Chapter I. INTRODUCTION

GENERAL STATEMENT

This thesis is based upon field work carried on during the summer of 1945, under the Geology Section of the Research Council of Alberta, and upon office work during the winter of 1945-46, in the Department of Geology at the University of Alberta, Edmonton. The writer was in the full time employment of the Research Council of Alberta and the full cost of the investigation was born by that organization.

This thesis forms the basis of the report to be submitted to the Research Council of Alberta, and consequently is somewhat more inclusive than such a thesis would normally be.

The investigation was directed primarily towards a study of the coal resources of the area. Consequently, field work was restricted to that part of the area underlain by Mesozoic rocks.

LOCATION AND ACCESSIBILITY

The Highwood-Elbow area is shown in Plate I, a geological map of the area. It is part of a narrow basin of Mesozoic rocks, lying to the west of the Highwood range, which here forms the easternmost range of the Rocky Mountains. The area covered in this report extends from township 16, range 5, west of the 5th meridian to township 20, range 8, west of the 5th

meridian. It averages five miles in width, and covers approximately one hundred and fifty square miles.

This area lies about twenty-five miles due west of the Turner Valley oil field. The southern part may be reached from Longview, in the southern part of Turner Valley, over a fair road, a distance of twenty-eight miles. From Turner Valley post office a road extends up Sheep River valley to the eastern edge of the Highwood-Elbow area. The first twenty miles of this road are in fair condition, but the last eleven are frequently impassable. Lumber roads extend up McPhail creek and Loomis creek from the Highwood river, but are safe for travel only in dry weather.

The rest of the area is accessible only by pack trail. The trails are in good condition. The main trail follows up Highwood river and Storm creek, and enters the Kananaskis drainage basin over Highwood Pass, which lies at an elevation of about 7,300 feet. Another trail follows up Mist creek and crosses into Sheep River valley by Rickert's Pass, which lies at about 8,100 feet above sea level. This trail continues up Sheep River valley to the Elbow, where it joins a trail running from Kananaskis lakes to the foothills. From the Highwood, a trail follows Etherington creek to Cataract creek, and south. Another trail leaves the Highwood at the mouth of Fitzsimmons creek, and crosses the Continental Divide near the headwaters of Baril creek by the Fording Pass, at an elevation of about 7,500 feet.

PREVIOUS WORK

The first geological work in the area was that done by Dr. G. M. Dawson in the summer of 1884 (Dawson, 1886)*. Dawson's work, part of a reconnaissance of a large part of the Rocky Mountains of southern Canada, included the Highwood, Sheep, and Elbow drainage basins. D. D. Cairns (1908; 1915) mapped part of the Sheep River basin. The first detailed geological work was carried on by B. Rose in 1918-19 (Rose, 1919), in the southern part of the area. The northern part was included in the area mapped by J. R. Marshall in 1921-22-23 (Marshall, 1921; Jones, 1924). The coal deposits were studied by J. A. Allan (1921) in 1920. P. S. Warren (1932) collected the Rock Creek fauna in the Fernie formation near Burns Mine. Hage (1943) measured the section of the Fernie formation near Burns Mine in 1942. In addition, both coal properties in the area have been examined by consulting geologists and engineers.

Besides the reconnaissance map accompanying Dawson's report, only one detailed geological map covering any part of the area has been published. This is the Upper Elk and Upper Highwood Rivers sheet, published in 1924 (G.S.C. 1924) on a scale of 1:250,000.

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*Name and date, and in some cases, page numbers, refer to bibliography reference.

BASE MAPS

The following maps were used as bases for mapping: Upper Elk and Upper Highwood Rivers (topography), Pub. 1754, Geological Survey of Canada, 1920, scale 1:250,000; Palliser-Kananaskis Area, Pub. 1962, Geological Survey of Canada, 1923, scale one inch to two miles; Mount Head sheet, Map 814A, Bureau of Geology and Topography, 1944, scale one inch to one mile. The first two were enlarged to the scale of one inch to one mile for field work. They contain large inaccuracies and are rather generalized. Consequently, the accuracy of the geology on these two sheets depends to a certain extent upon the local accuracy of the base maps.

ACKNOWLEDGMENTS

The writer wishes to express his thanks to those whose co-operation and assistance aided the progress of his work. T. F. Blefgen, J. A. Alexander, M. Meister, F. Nash and W. Walatir, officers of the Alberta Forest Service, and W. A. Slominski, Field Superintendent, Highwood Coal Mines, Limited, provided invaluable information and assistance, for which the writer expresses his sincere appreciation. D. G. Penner, of the Alberta Petroleum and Natural Gas Conservation Board, kindly permitted the writer to examine well samples in the Conservation Board office. J. Crawford, Chief Inspector of Mines, of the Province of Alberta, also aided the writer and is sincerely thanked.

Thanks must also be extended to the members of the Department of Geology at the University of Alberta. Dr. J. A. Allan, under whose direction the work was carried out, gave invaluable assistance, advice and encouragement. Dr. P. S. Warren determined the fossil collections. Dr. R. L. Rutherford directed the writer's thinking to a large extent, in the consideration of the sedimentary petrology.

C. A. Barber, packer, G. H. Bull, student geological assistant, and C. T. McNichol, cook, performed their field duties satisfactorily.

Chapter II. SUMMARY AND CONCLUSIONS

The Highwood-Elbow area, as shown on Plate I, is underlain by beds of Paleozoic and Mesozoic age, while unconsolidated deposits of Glacial and Recent age mantle part of the surface.

The Spray River formation of Triassic age lies with an erosional contact upon Paleozoic beds, which are probably of Pennsylvanian age. The thickness of these Triassic marine beds varies from 250 to 340 feet. The marine Fernie formation, 750 feet thick, is of Jurassic age and rests on the eroded surface of the Spray River formation. The non-marine Kootenay formation is of Lower Cretaceous age and overlies the Fernie formation with a sharp contact. The Kootenay formation varies from 709 feet to a possible maximum of 2,100 feet in this area. Important coal seams occur in the lower part of the Kootenay formation. The Kootenay formation is overlain by the Blairmore formation which includes both marine and non-marine beds. The Blairmore formation, from 2,500 to 3,000 feet in thickness, is also of Lower Cretaceous age. At the top are volcanic tuffs correlated with the Crowsnest Volcanics. The beds overlying the Blairmore formation are assigned to the Lower Alberta formation of Upper Cretaceous age. A maximum of 600 feet of beds of this formation are present in this area, with the top not exposed.

The structure of the area is similar to that of the eastern Rocky Mountains, but deformation has been more intense due to the incompetency of the Mesozoic beds. The regional strike is N 25° W. West-dipping thrust faults, usually dipping over 55 degrees, are the prevailing structural feature. The only major fold in the area is a syncline which occupies the upper valley of Highwood river. Minor folding is common. Transverse faults are also present.

The coal deposits lie in the Kootenay formation, usually in the lower part. Forty-eight to over seventy feet of coal in from 500 to 1,500 feet of section, may be present in the Kootenay formation in different parts of the area. The coal is mostly low volatile bituminous, with some semi-anthracite on Sheep river. The ash content is rather high. Most of the coal exposed is badly crushed. An estimate of the coal above an elevation of 4,500 feet, in seams of four feet or over, in an area of 23 square miles, showed a reserve of 1,630,000,000 tons. Development of the coal in this area has not progressed past the prospecting stage.

The sediments of the area are chiefly clastic, except in the Spray River formation, where gypsum in small quantities and calcite probably represent chemical precipitates. The clastic sediments in the Spray River formation were probably derived largely from the east, with a small amount from the west. The other formations are believed to have derived most of their

sediments from the Selkirk Mountains. The sandstones at the top of the Fernie formation are the first reflection of the uplift of the land mass to the west, which provided the sediments for the Kootenay and Blairmore rocks. Igneous masses were exposed in the Selkirks during Blairmore time.

The sediments of the upper Fernie, Kootenay, Blairmore and Lower Alberta formations appear to be a continuous series, showing the complete transition from marine to continental and continental to marine deposition. There is a cyclic pattern in the grain size, with the basal conglomerate of the Blairmore formation marking the peak of the cycle. Similarly, rock fragments and chert increase upwards to a maximum in the upper part of the Kootenay formation and then decrease slightly. The amount of feldspar and other minerals of igneous origin increases upwards to a maximum in the upper part of the Blairmore formation. The sandstone at the top of the Fernie formation probably represents a beach sand. The basal Kootenay sandstone may be partly eolian in origin. Most of the non-marine deposits are formed in rather small shallow bodies of water.

Increased precipitation, causing an increase in the size of the basins of sedimentation and an increase in the competency of the rivers, may be indicated by the basal Blairmore conglomerate, which maintains essentially constant characteristics throughout the area.

Vulcanism in the Crowsnest Pass at the close of Blairmore time is reflected in the Highwood-Elbow area by tuffs. The Crowsnest Volcanics were probably eroded almost contemporaneously with deposition, as the feldspars in an arkose in the Blairmore formation of the Highwood-Elbow area are euhedral and could not have been transported far. Vulcanism continued into Lower Alberta time.

Coarse sandstones near the base of the Lower Alberta formation are probably formed from material derived from the Blairmore formation.

Chapter III. GENERAL CHARACTER OF THE AREA.

DRAINAGE

The drainage of the entire area is tributary to the Bow river. The largest stream is the Highwood river, which is formed by the junction of Storm creek and Mist creek, southeast of Mist mountain. Storm creek, the larger of the two, rises on the west slope of Storm mountain in the Misty range. Mist creek rises on the east slope of Storm mountain. Highwood river flows southeast from the junction of these two creeks, along a synclinal axis for about fifteen miles, then swings gradually to the east and cuts through the Highwood range in sections 35 and 36, township 16, range 5, west of the 5th meridian.

Apart from Storm and Mist creeks, the tributaries of the Highwood are small. Odlum, Bishop, McPhail, Fitzsimmons and Etherington creeks are the principal streams entering the Highwood from the west and south. Cataract creek, which enters the Highwood east of the map area, drains the southern part of the Highwood drainage basin. Picklejar creek, Lineham creek, Cat creek and Stoney creek enter the Highwood from the east and north.

Sheep river rises in townships 19 and 20, range 7, west of the 5th meridian, and flows southeast in a broad glaciated strike valley, for a distance of about five miles. It then swings to the east, and cuts through the Highwood range. It joins

the Highwood river east of Okotoks. Sheep river is a much smaller stream than the Highwood, but occupies a very large valley. Its tributaries are all small in this area. Burns creek is the largest of these. Rae creek is the principal stream at the source of Sheep river.

A small part of the area is drained by the Elbow river, which rises in Misty range, north of Mount Rae. The Elbow flows at right angles to the strike across the area. The Little Elbow river drains the extreme northern end of the area.

Pocaterra creek rises near Storm creek, but flows northwestwards for about four miles. It then swings farther towards the west, passes through the High Rock range and flows into Kananaskis river a few miles below Kananaskis lakes.

PHYSIOGRAPHY

The Highwood-Elbow area, as here considered, consists of part of a basin of Mesozoic rocks which lies to the west of the Highwood range of the Rocky Mountains. The western side of the basin is marked by the High Divide range. Although this area lies within the Rocky Mountains, the topographic expression of the Mesozoic rocks is more closely akin to that of the innermost foothills than to the rugged peaks formed by Paleozoic limestones. Over most of the area, the relief is greater than in the foothills. The major features of the area are due to normal processes of erosion, but glaciation has exerted a strong influence upon land forms.

The topography of the Mesozoic basin is generally subdued, although the relief is frequently great. The lowest elevations occur along Highwood river, which, at the entrance to the gap through the Highwood range in sections 35 and 36, township 16, range 5, west of the 5th meridian, lies at about 4,875 feet above sea level. Sheep river in section 14, township 19, range 7, west of the 5th meridian lies at an elevation of about 6,100 feet. The highest elevations underlain by Mesozoic rocks occur on some of the ridges running east from Misty range, which reach almost 9,000 feet. The total relief therefore, is over four thousand feet, while local relief approaches 3,000 feet. Usually, however, the local relief varies from 500 to 2,000 feet.

Rickert's Pass, between Mist creek and Sheep river, lies at about 8,100 feet above sea level. The valley of Mist creek, below, is at an elevation of about 6,900 feet, while Sheep river, as stated above, lies at about 6,100 feet. Hence, the pass is very steep. The Highwood Pass, between Storm creek and Pocaterra creek is very gradual, however. The slope on the south side is about one hundred and seventy feet to the mile, while on the north slope, the gradient is only slightly greater.

Three mountain ranges formed of Paleozoic rocks occur within or at the edges of the area. The Highwood range, the outermost range of the Rocky Mountains, lies on the east side. Mount Head (which is outside the map area shown on Plate I) rises to 9,114 feet. The High Rock range, on the west side of the area,

forms the continental divide in this part of Alberta. The peaks of this range seldom extend above 9,500 feet. Misty range, which starts northwest of the junction of Mist and Storm creeks, is the loftiest in the area. Mist mountain, at the south end of the range, is 10,303 feet above sea level. Mount Fae, farther north, reaches to 10,576 feet.

The physiography of the area is very closely related to the lithology of the rocks occurring at the surface. Reference should therefore be made to the Stratigraphic Table in Chapter IV, during the following discussion of the relationship of the physiography to bedrock.

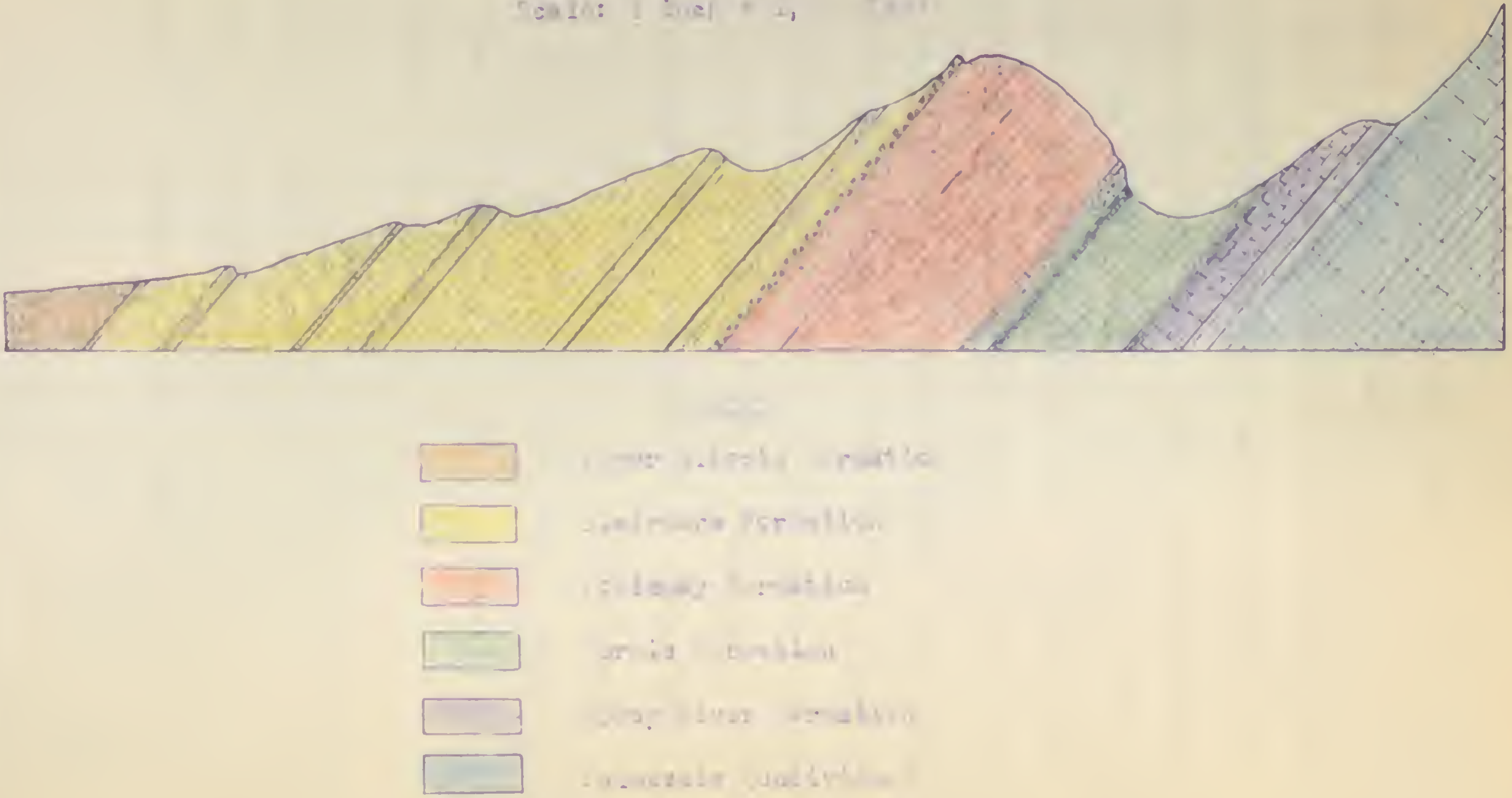
The Paleozoic beds are largely hard, massive limestones, which rise steeply above the softer Mesozoic beds. There is considerable variation in the hardness of different beds in the Mesozoic succession, which is reflected in the topography. Figure 1, a diagrammatic section, was prepared to illustrate this point. The structure sections also show the relationship, but not so clearly, due to a much smaller scale.

The lower part of the Spray River formation consists of soft shales which form a narrow trench or terrace at the contact of the Mesozoic and Paleozoic beds. The upper part of hard siltstones and sandy carbonates forms dip slopes. Saddles and valleys are formed in the soft shales of the lower part of the overlying Fernie formation. Outcropping as a steep face on hillsides, the massive sandstone at the top of the Fernie protects some of the shales

Figure 2.

[illegible]

Scale: 1 inch = 4, [illegible] feet



beneath it. The ridge then generally rises, as the overlying Kootenay formation is fairly resistant to erosion, particularly the upper sandy part. This ridge-forming habit is intensified by the hard, very resistant basal Blairmore conglomerate, which lies on top of the Kootenay, and usually forms a dip slope near the crest of the ridges. Where the upper Kootenay is soft, however, this conglomerate is too thin to develop as a strong ridge. Down dip the ridge falls away rapidly, due to the generally soft nature of the Blairmore formation, but may be interrupted by gentle ridges caused by thick sandstones in the Blairmore. This downward slope passes without interruption over the very soft Lower Alberta formation.

The above is very generalized. Other factors frequently modify these relationships. Streams flowing along strike and eroding down dip obscure the effects of the various beds. Interstream ridges show the effects on a small scale. Misty range, consisting of Paleozoic beds thrust on Mesozoic, seems to have protected the Mesozoic beds to the east of it.

Glaciation has had a marked effect upon the details of the physiography. Almost every valley in the area is U-shaped (see Plate IV). Cirques are well preserved at the heads of many valleys rising in the Paleozoic rocks. Hanging cirques are present on the east side of Misty range. The valley glaciers, which had the greatest effect upon the physiography, probably did not extend much above 7,500 feet elevation. Below this height, the mountains are rather subdued in outline. Above, the mountains become sharp

Plate IV. Looking northwest up Sheep River valley from Sheep-Highwood divide, showing glaciated U-shaped valley of the Sheep. Note large size of the valley compared to size of the stream. Highwood range on the east, Misty range on the west. Elbow and Little Elbow rivers in background.

and rugged. This is clearly shown in the Highwood range at Highwood river. The lower mountains at the south are rounded, while the higher mountains on the north side of the river are extremely rugged, towards their tops.

A topographic anomaly occurs at the divide between the Sheep and Elbow rivers. The divide is very low. Some small lakes which normally drain to the Elbow, also have channels leading towards the Sheep. Although the divide is occupied by both Paleozoic and Mesozoic rocks, there is no topographic expression of this. Considerable till occurs nearby. The valley of the Elbow, within the Mesozoic basin, is cut in water-laid gravels, and has barely reached bedrock. As noted above, the valley of the Sheep is disproportionately great for the size of the stream, and for the size of the area drained. Sheep River valley has not been modified by water action since glaciation,to any large extent.

The valley of Sheep river is a continuation of the valley of the Elbow, from the general appearance of the topography. The writer at first considered that post-glacial damming of the Elbow diverted its waters into the Sheep River valley, but this is untenable, as the Sheep valley is an almost unmodified glaciated valley, and post-glacial erosion consequently could not have excavated it.

It thus becomes necessary to consider pre-glacial time. A sequence of events can then be developed. It is believed that in late Tertiary time, the ancient Elbow river headed in the Highwood range, and the old Sheep river drained that part of the area

now drained by the upper Elbow. Headwall erosion by the old Elbow finally cut through the Highwood range, and captured the upper part of the ancient Sheep. This left the large Sheep River valley with a very small drainage basin. Glaciation occurred, modifying the Sheep valley and depositing till on the divide. Late glacial or post-glacial laking on the Elbow partly filled the channel of the Elbow with gravels. Removal of the barrier permitted the Elbow to cut down again in its valley to bedrock.

Laking has occurred on the Highwood river. Two well-preserved terraces are present. The lower lies about four feet above normal water level and has probably been modified by river action. It may be largely a flood plain, although its wide extent, from the Highwood range to the mouth of McPhail creek, is opposed to that. The second is well developed near the mouth of Stony creek, and in the vicinity of Cat creek. The top of this second terrace lies about 53 feet above the lower at Stony creek and about seventy feet near Cat creek. Remnants of terraces occur above Lineham creek. Traces of at least two terraces are indicated on Storm creek, near its mouth, at an elevation of about 5,900 feet. The valley of Lineham creek has a veneer of up to 100 feet of water-laid gravels which have evened out the floor of the valley and obscured much bedrock. This is probably due to laking within the basin itself, as the gravels are higher than any terraces seen on the Highwood. Similar deposits occur on Picklejar creek and some of the smaller creeks in the same vicinity.

Two prominent abandoned channels and several smaller ones occur near Highwood river. The first lies about half a mile east of the Highwood and extends from Lineham creek to near the bend of the Highwood at the mouth of McPhail creek (see Plate V). This channel is now a fairly flat meadow, with a ridge of Kootenay and lower Blairmore strata to the east and a bank up to fifty feet high on the west. Small alluvial fans, usually less than three hundred feet across, produce small irregularities on the bottom of the channel. The northern end of the channel is open and slopes towards the Highwood. The south end is blocked by gravels.

The Highwood now flows in a fairly open channel above Lineham creek. Near the mouth of Lineham creek the channel becomes deeper and canyon-like. This canyon persists almost to the mouth of McPhail creek. The extent of the canyon coincides almost exactly with the extent of the abandoned channel.

The writer offers the following explanation for the origin of the abandoned channel. That laking has occurred on the Highwood is shown by the terraces. The Highwood, in pre-glacial time, occupied the now abandoned channel. Laking occurred, causing the stagnation of tho Highwood with loss of erosive power. Streams draining the eastern slope of the Highwood valley and emptying into the lake,dropped their loads of sediment into the channel of Highwood river and raised its level above the level of the channel above Lineham creek. When the lake was drained, the Highwood was forced to seek a new channel. The Highwood cut down rapidly, forming the

Plate V. Looking northwest along deserted channel of the Highwood below Lineham creek. (Photo courtesy Dr. J. A. Allan).

canyon and leaving the old channel abandoned. Above Lineham creek the channel of the Highwood is far enough from the east slope of the valley to escape filling.

The other principal channel lies north of Highwood river, east of Cat creek. It is much narrower, with a more irregular course, than the other channel (see Plate VI A). The south bank of the channel reaches seventy-five feet in height, while the north bank is a high ridge of Kootenay and lower Blairmore strata. The upper (western) end of this channel is blocked by gravels. The lower end opens into Highwood valley proper.

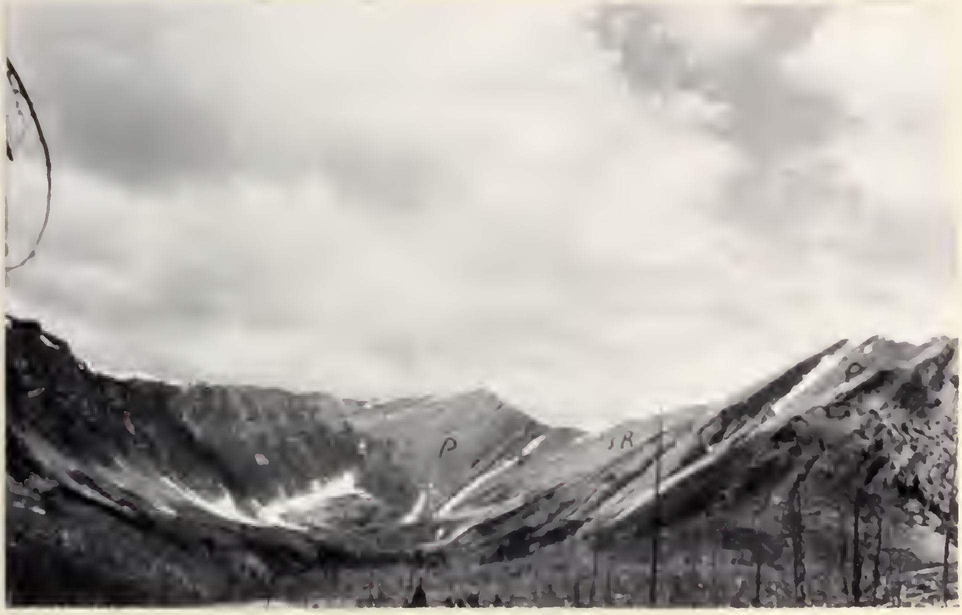
The upper part of Cat creek flows through a fairly gentle valley. In section 12, township 17, range 6, west of the 5th meridian, it enters a sharp canyon almost half a mile in length. This canyon is very little wider than the stream itself and is about one hundred feet deep. It is cut almost at right angles to the strike of the bedrock. Small waterfalls are formed by hard Kootenay sandstone and the basal Blairmore conglomerate. Cat creek then flows out into a fairly broad valley cut in gravels and empties into the Highwood.

Between the upper end of the canyon and the upper end of the lower abandoned channel, the surface slopes gently towards the southeast. No bedrock is exposed and indications are that much of the flat is underlain by gravels. This is certainly the case at the upper end of the abandoned channel, where twenty feet of gravel is exposed. The writer suggests that this channel is the course of pre-glacial Cat creek. During the laking postulated o e

Plate VI. A. Looking southeastwards down deserted channel of Cat creek. Note outcrops of basal Blairmore conglomerate on left bank in middle distance, showing slight displacement due to transverse faulting. (Photo courtesy Dr. J. A. Allan).

B. Paleozoic beds (P), thrust on lower Fernie (F) and Spray River (SR) along the Second Fault. North side of Lineham creek valley.

A



B

above, Cat creek would deposit what sediment it carried when it entered the still water of the lake, developing a deltaic type of deposit. Some of the gravels at the mouth of Cat creek and the gravels above the upper end of the abandoned channel are believed to represent this deposit. These gravels would block the old channel, while Cat creek would probably flow over the top of the gravels, changing its course by deposition. When the post-glacial lake was drained, the gradient of the lower end of Cat creek would be fairly steep and Cat creek would cut down through the gravels along whatever course it happened to be following at the time. Its pattern would thus be superimposed upon the bedrock and it would cut down through the bedrock, forming the canyon. The former channel would thus be left.

Above Cat creek a small abandoned channel exists, which probably acted as a tributary to pre-glacial Cat creek, gathering some of the drainage from the northeast slope of Highwood valley.

CULTURE

The area is largely unsettled. The only permanent residents are the Forest Service officers. At present, lumbering is the most important industry. A small mill operates on Loomis creek. During the summer cattle are pastured in the Highwood and Sheep valleys. Some trapping is carried on in the winter. Intermittent preliminary work on the coal deposits has been carried on and at the present time there are two camps for this purpose, one on the Highwood, one-quarter of a mile west of the Sentinel Ranger Station, and one on the

Sheep at Burns Mine. Fishing, hunting and camping attract numerous visitors to the Highwood.

FAUNA AND FLORA

Game is fairly abundant in the area. Deer, elk, moose, mountain sheep and black, brown and grizzly bear are present. Mountain goats occur on the High Rock range. Trout are quite abundant in some of the streams and small lakes.

Below the timber line, which lies at about 7,000 feet, most of the area has been forested but fires have destroyed much of it. Spruce, jack pino, limber pine and larch (tamarack) are quite abundant. Aspen occurs in small groves at low elevations. The heaviest stands of timber occur on the headwaters of McPhail, Loomis and Odlum creeks. A good stand lies on the upper part of Mist creek. A small area on Stony creek has some logs up to eighteen inches in diameter. The largest timber, up to two feet in diameter, was seen on Picklejar creek.

Chapter IV. STRATIGRAPHY.

GENERAL STATEMENT

The Highwood-Elbow area is underlain by beds of Paleozoic, Mesozoic and Recent age. Table I. summarizes the stratigraphy of the area. Since the investigation in the field was directed primarily towards the coal deposits, most of the emphasis was placed on the Mesozoic succession.

PALEOZOIC ERA

Beds of Paleozoic age form the Highwood, Misty and High Rock ranges of mountains. These beds are dominantly calcareous and dolomitic, with some clastic materials sometimes present. Chert occurs in the upper part of the series, as nodules.

The beds at the top of the Paleozoic succession are largely dolomites, and sandy dolomites are of frequent occurrence. A horizon with abundant silicified Spirifer shells usually occurs a few feet below the top. Below this horizon, dense light grey fine-grained dolomites and at least one four-inch bed of phosphate rock occur. These uppermost beds usually support a growth of black and green lichens, giving the outcrop a dark color.

Few fossils were collected from these uppermost beds. The following forms are present:

Crinoid stem joints
Spirifer, two species
Plagioglypta? sp.
Fish plates or teeth

TABLE I.
Stratigraphy of Highwood-Elbow Area

Era	Period	Epoch	Formation	Thickness	Lithology
Cenozoic	Glacial and Recent			0 - 150 feet	Till; lake and stream gravels and sands; calcareous tufa
		Great erosional unconformity			
Mesozoic	Cretaceous	Upper Cretaceous	Lower Alberta	600± feet	Dark grey shales and sandy shales; minor sandstone and limestone beds; pebble conglomerate; altered volcanic tuff. Marine.
		Erosional unconformity?			
		Lower Cretaceous	Blairmore	2,500± feet	Lower 700 feet, dark shales and sandstone; limestone. Conglomerate at base. Upper, greenish shales, sandstone, arkose, conglomerate; red shale and volcanic tuff at top. Marine and non-marine.
			Erosional unconformity		
			Kootenay	700-2,000 feet	Dark grey to brown sandstones, shales; coal; cannel; lenses of pebble conglomerate. Non-marine.
	Jurassic	Upper and Middle Lower ?	Fernie	750 feet	Largely dark grey shales and sandy shales; sandstone at top. Marine.
		Erosional unconformity			
	Triassic	Middle and Lower	Spray River	250-360 feet	Sulphur Mountain member (lower) 250 feet, dark grey, brown-weathering, silty carbonates and shales. Whitehorse member (upper) 0 - 110 feet; light grey calcareous sandstones, sandy limestones, silicified Lingula coquina. Marine.
		Erosional unconformity			
Paleozoic					Limestones, dolomites, calcareous sandstones, chert, shale.

The small fauna is insufficient to assign a definite age to the uppermost Paleozoic beds. The *Spirifer* species are closest to Pennsylvanian forms of the *S. rockymontanus* type. This would place these beds in either uppermost Rundle or in Rocky Mountain formation. The sandy dolomites and phosphate below the *Spirifer* zone are lithologically similar to the Rocky Mountain formation of the Banff area (Warren, 1927, p. 34). It is probable that in this area the Rocky Mountain formation is present at the top of the Paleozoic succession.

MESOZOIC - PALEOZOIC CONTACT

The Paleozoic beds are overlain by strata assigned to the Spray River formation of Triassic age. There is thus a considerable time interval between the uppermost Paleozoic beds, probably of Pennsylvanian age, and the Triassic. The actual contact, however, is hard to find as the basal Spray River bed closely resembles the Paleozoic.

The contact was found well exposed in only one spot, on a small creek in the northeast quarter of section 7, township 17, range 5, west of the fifth meridian. The contact is erosional. The surface of the Paleozoic bed is marked by small depressions up to one and one-half inches in depth and from four to six inches across, where the softer portions of the bed have been eroded. (See Plate IXA). The basal bed of the Spray River formation lies on this surface and extends down into the depressions.

Throughout the rest of the area, where the eroded surface of the Paleozoics was not observed, it is difficult to draw the contact on lithological grounds. However, since only about four feet of beds at the base of the Spray River formation resemble the Paleozoic rocks, the approximate contact is readily obtainable.

MESOZOIC ERA

TRIASSIC SYSTEM

Spray River Formation

Name. The Spray River formation was first defined by McConnell (1886, p. 15) under the name "Upper Banff shales". E. M. Kindle in 1924 (quoted in Shimer, 1926, p. 2) proposed the term "Spray River formation" for this group of beds in the Banff district. Kindle's term has been used since.

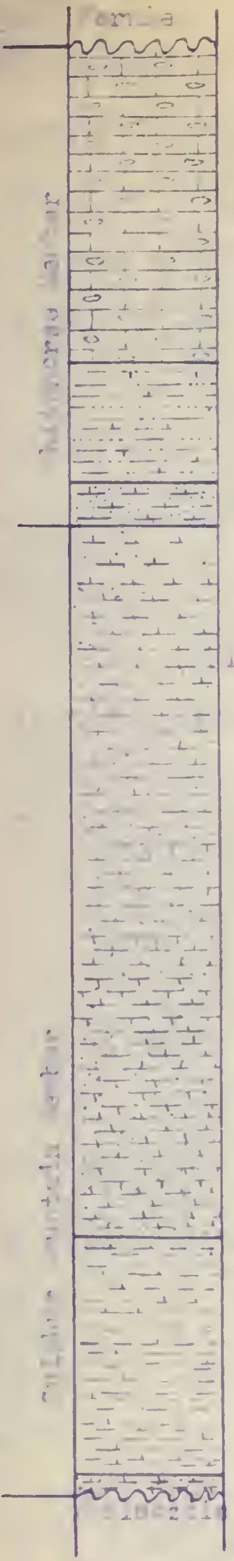
Distribution. The Spray River formation in the Highwood-Elbow area outcrops as a narrow band on the updip side of the Paleozoic beds. It occurs about the southeast end of Mist mountain and underlies part of the divide between Sheep and Elbow rivers. Much of the area between Elbow and Little Elbow rivers is also underlain by this formation.

Thickness. The Spray River formation varies in thickness from 240 to 360 feet, in the area. The maximum thickness was observed on the south side of Picklejar creek. Variations in thickness are due largely to erosion of the top of the formation in pre-Fernie time, as the shale in the lower part of the formation shows no important variations in thickness throughout the area.

Description. The Spray River formation consists of a series of shales, sandstones and silty and sandy limestones and dolomites. The formation contains two members which are correlated on lithology with the Sulphur Mountain and Whitehorse members, recognized farther north (Warren, 1945). The lower member is the Sulphur Mountain member, while the upper is believed to represent some part of the Whitehorse.

The lower member consists of dark grey to dark brown shales, calcareous and dolomitic siltstones and a little sandstone. The base is represented by about four feet of hard, fine-grained, dark grey calcareous sandstone, which rests upon the eroded surface of the Paleozoic. The top of this sandstone is thin-bedded and pyritiferous. Fifty to seventy feet of dark grey to dark brown calcareous fissile shales overlie the basal sandstone. These grade upwards into dark grey, hard, reddish-brown weathering carbonate rocks which carry a large percentage of silt and very fine sand. These rocks are well-bedded, occurring in beds from one-half inch to four feet in thickness, but averaging about three inches. Ripple marks are not uncommon. The distinctive color of these beds when weathered stands out sharply against the grey of the Paleozoic rocks..

The Whitehorse member appears to overlie the Sulphur Mountain member conformably. The upper member consists of a series of light grey, white and pink limestones and calcareous sandstones. All the beds carry considerable sand. Several beds in the lower forty feet are very fossiliferous and some approach coquinas. The coquinas



[illegible] feet	Tan, [illegible] and light gray, [illegible] sandy limestone, [illegible] chert
25 feet	Sandy and cherty [illegible], partly [illegible]
11 feet	Light gray, fossiliferous, [illegible] sometimes [illegible] and silicified
[illegible] feet	Brown weathering, dark gray, calcareous and [illegible] [illegible] ½ [illegible] = to [illegible] feet thick; [illegible]
[illegible] feet	Dark gray [illegible] calcareous shale
[illegible] feet	Hard, light gray, [illegible] sandstone, [illegible]

Figure 2. Columnar section of [illegible] River Formation in sec. [illegible], T. [illegible], R. [illegible], on [illegible] of [illegible] creek. Scale: 1 inch = [illegible] feet.

consisting largely of small *Lingula* shells, are frequently silicified. The upper part of the member consists of grey-weathering, grey and pink calcareous sandstones in beds about two feet in thickness. Chert nodules occur sparingly. These hard beds closely resemble the upper part of the Paleozoic. The maximum development of the Whitehorse member was observed on Picklejar creek, where 116 feet of beds were assigned to this member. Towards the south, the entire Whitehorse member has been eroded away, while only about forty feet of the lower beds are found on Sheep river, to the north.

The best exposure of the general section is on the south bank of Picklejar creek, near its source. Here, three hundred and fifty feet of beds were measure in the following section:

Overlying beds, Fernie formation	
Erosional unconformity	
Whitehorse member:	
White to light grey and pink, hard, calcareous sandstones with some chert nodules	80 feet
Sandy and shaly limestone, partially concealed	25 feet
Light grey, partially silicified, sandy limestone and coquina	11 feet
Sulphur Mountain member:	
Brown-weathering, dark grey, sandy and silty carbonates in beds one-half inch to four feet; scattered *Lingulas* . .	180 feet
Dark grey to dark brown fissile calcareous shales, grading upwards to beds above	60 feet
Hard, dark grey, calcareous sandstone, pyrite at top	4 feet
Total thickness of section -	360 feet
Erosional unconformity	
Underlying beds, Paleozoic sandy limestones	

Phosphate is present in most of the beds of the Spray River, but in very small quantities. The basal bed and Lingula coquinas show the greatest amount. Gypsum, determined microscopically, occurs throughout the formation in small quantities, but is most abundant in the Whitehorse member.

Age and Correlation. The formation is generally sparsely fossiliferous, but the fossils are rarely well-preserved. The following were obtained from the Sulphur Mountain member:

Lingula sp.
Perna? sp.

The Whitehorse member is very fossiliferous in its lower part, but identifiable specimens were not collected. The fossils include abundant Lingula and about three species of pelecypods, unidentifiable even to genus.

There were no fossils collected which can be used for correlation. Consequently, correlation is based upon stratigraphic position and lithology. The Lingula of the Sulphur Mountain member, however, closely resembles Spray River forms.

Shimer (1926, p. 4) describes the Spray River formation at Lake Minnewanka as "An alternation of heavy bedded, light grey, calcareous sandstones and thin-bedded, dark grey, calcareous-arenaceous shales. The latter are especially conspicuous for their numerous black laminae. The shales often weather reddish."

Warren (1945, p. 482) states, "The Spray River formation may be divided quite naturally into two members: the lower member consisting of dark grey to black, laminated shales, and dark grey,

fine-grained limestones or dolomites which we may designate the Sulphur Mountain member . . . . and secondly, the upper member of light grey to whitish limestones, dolomites, sandy dolomites or sandstones with sometimes an intermixture of darker shales, and to the north, evaporites such as gypsum. The name already in use by field geologists for this succession of beds is the Whitehorse member."

From these descriptions and from comparison with specimens in the collections of the Department of Geology at the University of Alberta, the writer has no hesitation in assigning these beds to the Spray River formation. The description of the two members by Warren might, with only slight modification, be applied to the two members in the Highwood-Elbow area. Of especial importance is the presence of an appreciable amount of gypsum in the Whitehorse member in which considerable gypsum has been found at the north boundary of Jasper Park (Allan, 1932, 1933). Consequently, the lower member has been correlated with the Sulphur Mountain member, while the upper has been correlated with the light-colored Whitehorse member.

According to Warren, the age of the lower part of the Sulphur Mountain member is Lower Triassic, while the upper member is Middle Triassic. The boundary between Lower and Middle Triassic may or may not correspond to the change in lithology (Warren, 1945, p. 487). Thus, the above correlation suggests that both Lower and Middle Triassic beds are present in the Highwood-Elbow area. Probably only the lower part of the Whitehorse member is present in the area.

JURASSIC SYSTEM

Fernie Formation

Name. The term "Fernie shales" was first used without definition by Leach (1903, p. 169), and has since been widely adopted. Before Leach's time, the Fernie shales had been included with the overlying Kootenay formation of Lower Cretaceous age.

Distribution. The Fernie formation outcrops in three bands in the area: along the west side of Highwood range, along the east side of Misty range and along the west side of Misty range. In addition, extensive areas near the Sheep-Elbow divide are underlain by these beds. The upper part is brought to the surface by thrust faulting between Lineham creek and the upper part of Mist creek.

Thickness. The Fernie is usually not well-exposed, due to the very soft nature of the beds. It is frequently folded or faulted. Consequently, an accurate measurement of the thickness is very difficult to obtain. Probably the best section in the area occurs on the divide between Cliff creek and Sheep river, near Burns Mine. Here, a well-exposed section measured 745 feet. Hage (1943, p. 8) gives a thickness of 653 feet to the base of the massive sandstone at the top of the Fernie, at the same locality. Since this sandstone is about ninety feet thick, the thicknesses closely agree. Other sections were not measured in detail, but the general thickness appears to be close to the value given above.

Description. The Fernie formation consists of a series

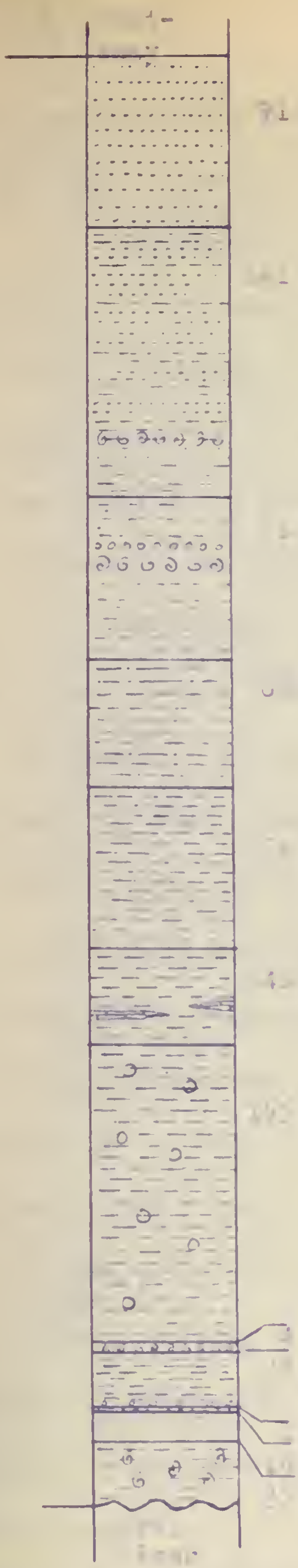
of shales and sandy shales, with one sandy zone about thirty-five feet above the base and a heavy massive sandstone at the top. The following section, measured near Burns Mine, gives the best idea of the relationships of the beds in the formation:

Overlying beds, Kootenay formation
Contact apparently conformable

Light brownish grey, fine-grained, hard, finely cross-bedded sandstone, with lenses of hard, dark grey, yellow-weathering sandstone	91 feet
Thin beds of sandstone similar to above, interbedded with grey sandy shales, the sandstone decreasing downwards. Some ironstone and sandy limestone . .	141 feet
Grey sandy shales, with ironstone nodules and thin, finely crossbedded sandstone. Some plant fragments	81 feet
Dark grey to dark brown, shale and sandy shale, some ironstone	65 feet
Black fissile shale	84 feet
Olive-grey, fissile shales with yellow-weathering limestone bands to one foot in thickness	46 feet
Black fissile shale weathering to thin flakes, with large dark grey, orange-weathering concretions in upper 100 feet; occasional *Belemnite* guards in lower part .	155 feet
Dark grey, buff-weathering, calcareous, highly fossiliferous siltstone; Rock Creek member	4 feet
Light grey siltstone and shale, with a few *Belemnite* guards; small phosphate nodules at base	28 feet
Sandstone, rich in pyrite, abundant *Belemnite* guards, and with many very small black phosphate nodules .	1.5 feet
Hard, black, thin-bedded sandstone	14 feet
Hard, black to dark brown, fissile calcareous shale, with thicker beds of black argillaceous limestone; fossiliferous	35 feet
Total thickness of section - -	745.5 feet

Erosional unconformity
Underlying beds, Whitehorse member, Spray River formation.

The base of the Fernie formation in this area apparently consists of dark shales, resting on the eroded surface of the Spray River formation. In many other areas of western Canada, the base is represented by a bed of phosphate rock (Telfer, 1933), but such



91 feet [illegible] gray, [illegible], [illegible], [illegible] [illegible], [illegible], gray, yellow-weathering [illegible]

141 feet [illegible] similar to [illegible], [illegible] gray sandy [illegible], [illegible] and sandy limestone. [illegible] fragments. [illegible].

[illegible] feet [illegible]

[illegible] feet [illegible];
[illegible]

[illegible] feet Black fissile [illegible]

[illegible] feet Shale, [illegible], olive gray [illegible] with yellow-weathering [illegible]

[illegible] feet Black fissile [illegible] fissile. [illegible] gray, [illegible]

[illegible] feet [illegible]
[illegible] feet [illegible], [illegible]
[illegible]
[illegible] feet [illegible], [illegible]
[illegible] feet [illegible], [illegible], [illegible]
[illegible] feet [illegible]

Figure [illegible]. [illegible]

a bed was not observed by the writer. If the phosphate horizon is present, it must be extremely thin.

The basal black shale is present throughout the area. It consists of soft dark brown to black fissile shales, similar to the "Poker Chip" shales of Turner Valley. Interbedded with these are discontinuous beds of black argillaceous limestone. Poorly preserved fossils are abundant. The shales are very soft and consequently, are usually thickened by faulting or folding.

Overlying these shales is a sandy and silty zone, at the top of which is a fossiliferous siltstone bed referred to the Rock Creek member. The lowermost bed in this series is a black, brown weathering, hard sandstone, usually calcareous. The rock is thin-bedded on Stony creek and very fine. Farther north, it becomes thicker bedded and a little coarser. The base of this bed is marked by casts of ripple marks. Above this sandstone is a thin bed of sandstone which contains numerous phosphatic nodules up to one-quarter of an inch in diameter, as well as pyrite and *Belemnite* guards. This bed could be easily mistaken for a fine conglomerate. Overlying this bed are almost thirty feet of light grey, sometimes brownish, calcareous and non-calcareous siltstones and shales, which carry phosphate nodules up to two inches in diameter at the base. These are overlain by a four to five-foot bed of dark grey calcareous siltstone which is very fossiliferous. This fossiliferous member is termed the Rock Creek member of the Fernie. Pyrite is quite abundant.

The black shales overlying the Rock Creek member contain, in the upper part, large argillaceous limestone concretions which sometimes reach five feet in diameter. The smaller ones are in the form of a flattened sphere, while the larger ones are more irregular. Cone-in-cone occurs frequently on the surface of the concretions.

The shales upwards become sandy and lighter in color, and thin sandstone beds appear. By a reduction in the amount of shale, the interbedded shales and sandstones pass into a massive sandstone forming the top of the Fernie formation. The interbedded sandstones and shales have been referred to as the "passage beds" or "transition beds", while the sandstone at the top has been referred to the Kootenay formation (McLearn, 1929, p. 101-102). The "passage beds" vary considerably in thickness, varying from eighteen feet just north of Highwood river on the west side of Highwood range, to 141 feet near Burns Mine.

Above the "passage beds" is a sandstone, which is 136 feet thick near the Highwood and 91 feet at Burns Mine. This bed is a light brownish grey weathering, brown fine-grained sandstone. It tends to spall off in flakes up to two inches thick, in a direction parallel to the face of the outcrop. Lenses of a very dense, very dark grey, yellow-weathering sandstone are interbedded with it.

Age and Correlation. The lowest fauna was collected in the basal black shale. It seems to be distributed throughout the forty feet of beds. The following fossils were collected:

Pseudomonotis sp.
Posodonomya? sp.
Oxytoma sp.
Chlamys? sp.
"Belemnites" sp.
Cylindroteuthis sp.

The largest fauna, both in species and specimens, lies at the top of the Rock Creek member. The following species were collected:

Foraminifera, several species
Rhynchonella webbi Warren
Grammatodon ferniensis Warren
Cucullaea rockymontana Warren
Inoceramus ferniensis Warren
Gryphaea cadominensis Warren
Oxytoma mclearni Warren
Entolium parviaure Warren
Modiolus sp.
Plagiostoma albertense Warren
Pleuromya burnsi Warren
Pleuromya cf. burnsi
Arctica subtrigonalis Warren
"Arctica" sp. nov.
Astarte, two species
"Pleurotomaria" sp.
Stemmatoceras albertense McLearn
Stemmatoceras mclearni Warren sp.nov.
Stemmatoceras sp.
Saxitoniceras cf. marshalli McLearn
Saxitoniceras ? sp. nov.
Saxitoniceras cf. allani McLearn
Teloceras dowlingi
Itinsaites itinsae McLearn
Kanastephanus sp.
"Belemnites" sp.

Fossils are not of common occurrence above the Rock Creek member. Some of the large nodules are occasionally fossiliferous, but it is not certain that the fossils always occur at the same horizon in this band. Only two species have been identified:

Entolium cf. *parviare* Warren
Miccocephalites sp.

Fossils are not uncommon in the upper sandy beds, but are poorly preserved. Two hundred feet below the top, at Burns Mine, *Lima* sp.nov. was collected from sandstones interbedded with shale. One and one-half miles northwest of the Highwood Coal Mines camp, the following forms were collected, about 110 feet below the top:

Oxytoma cf. *blairmorensis* McLearn
Modiolus cf. *frankensis* McLearn
Astarte sp.
cf. *Pachytheuthis densus* (Meek)
Plant fragments

The lowermost fauna, in the basal shale, consists of new species and hence is useless for correlation purposes.

The fauna of the Rock Creek member is large. The pelecypods are of little value for correlation, except to prove that the bed carrying them is to be correlated with the Rock Creek member in Crowsnest Pass (Warren, 1934, p. 66). The ammonites, however, clearly indicate a Bajocian (lower Middle Jurassic) age for the Rock Creek member and correlate it with the lower part of the Yakoun formation of the Queen Charlotte Islands (McLearn, 1929, p. 3).

The *Miccocephalites* fauna in Crowsnest Pass area has been assigned to the Callovian (early Upper Jurassic) by Buckmann(1929). It is there associated with the *Corbula munda* fauna (McLearn, 1929, p. 86), which lies 550 to 800 feet above the base of the Fernie formation. In the Highwood-Elbow area, *Miccocephalites* was found at only one locality, in a badly disturbed section where the Rock Creek member was not exposed. It occurs, however, in the limestone

concretion zone and thus is probably not over 250 feet above the base. Hence, a large part of the Fernie formation must be of Upper Jurassic age.

The small fauna from the "passage beds" and upper sandstone is not indicative of age, as none of the forms could be definitely assigned to a species and because the Jurassic pelecypods frequently have a long time range. However, this fauna made it possible to definitely assign the massive sandstone at the top of the "passage beds" to the Jurassic rather than to the Cretaceous. This fauna appears to be closely related to the *Corbula munda* fauna of the Blairmore section, although it apparently carries no species in common. The stratigraphic position of this small poorly preserved fauna is at least 350 feet higher than the *Miccocephalites* in this area. It probably represents a somewhat later time, although possibly still lower Upper Jurassic. The considerable stratigraphic interval and the change in sedimentation, however, strongly suggest that this fauna is somewhat later in time than the *C. munda* fauna.

Pelecypods identified specifically with fossils from McLearn's *C. munda* fauna were collected in the Rierdon formation on the Sweetgrass Arch in Montana, in association with *Arctocephalites*, which indicates a late middle Jurassic age for the beds (Cobban, 1945, p.1281). It is unfortunate that McLearn did not give the stratigraphic position of the *Miccocephalites* in the long-ranging *C. munda* fauna, as it appears that that fauna may extend from late middle Jurassic to early upper Jurassic.

From the faunal evidence, therefore, beds ranging from early middle to early upper Jurassic are represented in this area, with undated faunas both above and below.

CRETACEOUS SYSTEM

Kootenay Formation

Name. The name was first proposed by J. W. Dawson (1886) and by G. M. Dawson (1886), and included beds now assigned to the Fernie, Kootenay and Blairmore formations. It was restricted to include only the beds between the top of the Fernie formation and the thick conglomerate occurring above the coal-bearing beds, by Leach in 1911 (Leach, 1911, p. 194). This usage has since been generally followed.

Distribution. The Kootenay formation outcrops over a large part of the Highwood-Elbow area. Two main bodies of Kootenay strata are present. The more easterly, between Highwood river and Highwood range, consists of three bands of beds separated by faults, in the southern part of the area. North of Picklejar creek, only the two westerly bands continue north. The westerly group of outcrops comes to the surface on Bishop creek. Northwards, it splits about Misty range, one arm extending north along the east side and the other on the west side of the mountains.

Thickness. The most reliable measurement of the Kootenay formation, on the easternmost band of outcrops, two miles northwest of Highwood river, made by tape measure, gave a thickness of 709 feet.

Stadia measurements in the same region gave an average of seven hundred and fifty to eight hundred and fifty feet. A section measured immediately north of Highwood river, along a road cut and open pit coal prospect, showed a thickness of 1,090 feet, but this, as will be shown later, is probably in excess due to faulting.

No section was measured in the middle band of the eastern group. A section measured on Picklejar creek, by telemeter, gave a total thickness of 2,100 feet for the Kootenay strata on the western of these three bands. The writer believes that this is too thick, as it implies too rapid western thickening of the formation. However, the width of the outcrop of this western band stays fairly constant, showing that there has been very little deformation and this band of Kootenay must be very much thicker than the eastern band.

Due to great deformation of the Kootenay strata, no measurements were made on the formation west of Highwood river.

Description. The Kootenay formation is a series of dark-colored, fairly fine-grained, non-marine shales, sandstones and coal seams, with a few lenses of pebbles in the sandstones in the upper part. Ironstone occurs occasionally. There is considerable lateral variation in the section. In the southeastern part of the area, the formation is divisible into two members on a lithological basis. The lower consists of shales, coal seams and thin sandstones. This grades upwards by an increase in sandstones to the upper member, which consists principally of fine to coarse sandstones with a little interbedded shale. There is no marked contact between the two. Over

the remainder of the area the two members are less distinct, as the upper part becomes more shaly. Nowhere are the members mapable units.

The following section of the Kootenay formation was measured in section 5, township 17, range 5, west of the 5th meridian (see Plate IX B):

Overlying beds, Blairmore formation
Erosional unconformity

Coarse to medium grained, light grey, crossbedded, cherty sandstone, becoming darker towards base . .	58 feet
Carbonaceous, dark grey shale and lighter grey sandy shale	14 feet
Buff weathering, fine-grained, finely crossbedded, shaly sandstone	30 feet
Coarse grained, crossbedded, massive brown sandstone .	34 feet
Concealed, probably shale	7 feet
Dark grey, crossbedded sandstone, fine at top, but becoming coarser and carbonaceous towards base; lenses of chert pebble conglomerate up to 7 inches thick at base	21 feet
Dark brown, fine grained sandstone, shaly at top . .	4 feet
Carbonaceous and sandy shales, largely concealed . .	21 feet
Hard, fine to coarse grained buff to grey crossbedded sandstone; ironstone nodules at base	55 feet
Hard, coarse, dark grey cherty sandstone with lenses of very coarse sandstone and chert pebbles at base .	8 feet
Black carbonaceous shale	1 foot
Hard, massive, medium grained brown sandstone . . .	5 feet
Hard, fine grained, thin bedded silty sandstone, carbonaceous at base	3 feet
Grey sandstone, fine at top, becoming coarser and cherty towards base, thin beds of black shale near base . .	29 feet
Black to brownish grey shales and sandy shales . . .	38 feet
Hard, medium grained, dark grey, cherty sandstone with pyrite; imprints of large stems at base	10 feet
Hard, dark grey, very fine grained, yellow-weathering sandstone, with ironstone nodules and scattered chert pebbles one foot below top	6 feet
Shales, carbonaceous to sandy, partially concealed . .	46 feet
Buff weathering, fairly coarse, dark grey, hard sandstone	4 feet
Buff to yellow-weathering, dark grey to dark brown, shaly sandstone and sandy shale	40 feet

Carbonaceous and black, to grey, shales and sandy shales with thin beds of very fine hard, yellow-weathering, sandstone; some ironstone nodules; largely concealed	161 feet
Hard, medium grained, finely crossbedded, grey, cherty sandstone	16 feet
Carbonaceous to sandy shales, thin beds of hard, yellow-weathering sandstone, very fine, some ironstone; largely concealed	69 feet
Hard, light grey weathering, crossbedded, light to dark grey sandstone in beds up to one foot thick	29 feet
Total thickness of section - -	709 feet

Conformable contact
Underlying beds, Fernie formation.

The base of the Kootenay formation is arbitrarily drawn at the base of a light to dark grey, medium grained sandstone, which rests with a sharp, although apparently conformable contact on the much finer upper Fernie sandstone. This bed is included with the Kootenay formation because it is lithologically similar to some of the beds in that formation, while it marks a sharp break with the Fernie type of sandstone. At the top of the basal sandstone, black shales occur without any intergradation. This sandstone is usually crossbedded. Both light grey and dark grey phases occur, depending upon the proportion of quartz grains to dark chert and argillite grains. It is harder than the underlying Fernie sandstone and weathers almost white to slightly pinkish. It usually supports a prolific growth of black and green lichens, so that from a distance it appears black and is in marked contrast to the brownish grey sandstone beneath. (See Plate VIII B). The thickness of this bed varies from 19 to 30 feet. It appears to thin northwards.

The lower part of the Kootenay formation, consisting largely of shales with minor amounts of sandstone, and coal, is never well exposed. Shales are very carbonaceous and are dark grey to black in color. Ironstone nodules are fairly abundant. A characteristic rock of this lower part consists of a very fine, dark brown to black, orange-yellow weathering sandstone, which occurs in beds up to two feet in thickness. The surface, when eroded, appears to be corroded like a limestone, but the beds are rarely calcareous. Siderite seems to be present, however.

Most of the coal in the eastern part of the area occurs with the lower more shaly part of the formation. The upper four hundred feet appear to be barren of coal. In the western part of the area, thin coal seams and thin lenses of cannel occur in the upper four hundred feet of the formation. The coal is considered in detail in Chapter VI.

The upper part of the formation is lighter in color, much sandier, and generally coarser grained than the lower part. In the southeastern exposures of Kootenay, this is particularly well marked. Towards the northwest the sandstones become thinner-bedded and are generally finer. Of considerable interest are some thin beds exposed in the Kootenay formation in a road cut half a mile west of the Sentinel Ranger Station. One hundred and eighty feet from the top of the formation is a very coarse sandstone composed almost entirely of black grains of argillite and some chert. A somewhat similar bed, but with well-rounded, discoid pebbles up to three-eighths of an inch in diameter, occurs 284

feet below the top. A few white quartzite pebbles are also present. This bed is six inches thick. Lenses of black chert and argillite, and white quartzite pebbles also occur in some of the sandstones. These lenses are discontinuous. The pebbles are usually less than one inch in diameter. Frequently associated with these pebbles are ironstone nodules.

Crossbedding is prevalent in the Kootenay formation. It varies from very fine to very coarse. The finest is usually present in ripple marks.

The top of the Kootenay formation is marked by an erosional unconformity. The basal conglomerate of the overlying Blairmore formation rests on a very irregular surface of the Kootenay. In the band of Kootenay between the Highwood river and the location of the measured section given above, a distance of about two miles, a considerable thickness of beds has been removed by erosion. Near the Highwood the uppermost beds are thin sandstones with shales. At the north end massive sandstonesoccur at the top. Some idea of the amount of erosion can be gained from a consideration of the pebble zones. At the south end the uppermost pebbly sandstone occurs 246 feet below the top of the formation. At the north end the uppermost pebble zone occurs 143 feet below the top. While the pebble zones probably cannot be exactly correlated, they will occur, no doubt, at the same general horizon. Consequently, in a distance of two miles there is a stratigraphic difference of about 100 feet in the position of the unconformity at the top of

the Kootenay.

Age and Correlation. The only fossils collected from the Kootenay formation consisted of plants. These are quite abundant but represent only a small number of species. The plants have not been specifically identified but are of Kootenay type.

The age of the Kootenay formation has usually been considered to be Lower Cretaceous. However, an Upper Jurassic age for these beds has been suggested. This is due to two things. The plants are quite closely related to Jurassic forms. The Fernie has been regarded as grading up into the Kootenay, while the marked unconformity, below definitely Lower Cretaceous faunas, occurs at the top of the Kootenay.

In Montana the term "Kootenai formation" has been applied to the Lower Cretaceous group of beds underlying the Colorado shale, and underlying the Jurassic Morrison formation. The Kootenai includes a conglomerate or sandstone, the Cloverly conglomerate, which overlies the coal-bearing portion of the series (Lammers, 1939). Recently, the presence on the Sweetgrass Arch of an unconformity at the base of a massive sandstone,correlating with the Cloverly conglomerate, has been demonstrated (Cobban, 1945, p. 1281). Brown (1946) enlarged the Jurassic Morrison formation to include the coal-bearing beds below the unconformity. These coal-bearing beds had previously been correlated with the Kootenay of Alberta (McLearn and Hume, 1927). The flora of these beds is considered to be Upper Jurassic in age by Brown. Their flora is comparable with that of the Kootenay.

However, Bell (1945, pp. 11 and 12) states, "The known Kootenay flora, provisionally designated Neocomian-Barremian, is probably of Barremian rather than of Neocomian age, for the majority of its species pass onwards into the Aptian. The presence of some species closely allied to, and in some instances perhaps conspecific with, Jurassic species is of little significance, for all are long-ranging and most of them are included also in the later Aptian flora."

There is thus a considerable difference of opinion regarding the age of the flora.

Before the massive sandstone between the Fernie shales and the Kootenay formation was recognized to be of Fernie age, it was considered that the Fernie was transitional at the top into the overlying Kootenay. Beach (1943, p. 35) records an erosional unconformity at the top of this sandstone in the Moose Mountain area. The small suite of fossils collected from this bed by the writer clearly indicates that it is a marine Jurassic bed. The contact in the Highwood-Elbow area is not transitional, but abrupt, whether the contact be drawn at the base of the medium grained grey sandstone where the writer has drawn it, or at the base of the overlying shales.

The unconformity between the Kootenay and Blairmore formations has been emphasized by those who assign a Jurassic age to the Kootenay. In the Highwood-Elbow area, it was shown above that a considerable thickness of Kootenay beds have been removed by pre-

Blairmore erosion. However, in Chapter VI the writer attempts to show that petrologically the Kootenay-Lower Blairmore is a regular series and that the unconformity is more closely related to deposition of the conglomerate than to an extensive pre-Blairmore period of erosion. Thus, the writer believes that the stratigraphic significance attached to this unconformity is not justified.

It is therefore believed that the Kootenay formation in the Highwood-Elbow area is of Lower Cretaceous age. The statement of Bell is accepted and a provisional Neocomian-Barremian age is assigned to it.

To the north, a similar flora occurs in beds above marine Upper Jurassic faunas in the Nikanassin formation and below the Cadomin conglomerate.* In Montana, the coal-bearing beds below the Cloverly conglomerate probably correlate with it.

Blairmore Formation

Name. The Blairmore formation was separated from the Kootenay by Cairns (1908) who called it the Dakota, implying an upper Cretaceous age. Leach (1911) assigned the name "Blairmore formation" to these beds in the Crowsnest Pass and assigned them to Lower Cretaceous. The name is now used throughout the southern foothills. McLearn (1945) has termed it the Blairmore group, which is now followed by the Geological Survey of Canada. However, since it is a mapable unit in the Highwood-Elbow area, the writer prefers

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*C. R. Stelck, personal communication.

to retain the word "formation".

Distribution. There are several bands of Blairmore strata within the area. The most easterly follows north along Etherington creek and extends to within three-quarters of a mile of Cat creek, when it pinches out against a fault. The next band to the west crosses Baril creek and crosses Highwood river, being lost through faulting a few hundred feet north of Cat creek. The next band lies in a syncline which follows the upper part of the valley of Highwood river. From the mouth of McPhail creek, north to the east side of Mist mountain, this band is split in two by a narrow band of Lower Alberta shales. The synclinal belt of Blairmore formation is finally lost north of Burns creek. Blairmore beds also occur south of Bishop creek and follow the west side of the disturbed belt south and west of Misty range. A narrow band is brought to the surface by faulting on the east side of the High Rock range, on the divide between Odlum and Storm creeks.

Thickness. No accurate determination of the thickness of this formation was obtained, since covered intervals far exceed the exposed portions of the beds. Minor folding and faulting also thicken the formation. The best estimates that could be obtained in the region about the mouth of Lineham creek, where both top and bottom of the formation are exposed, gave a thickness of 2,500 to 3,000 feet for the formation, but these are probably somewhat excessive. The formation is believed to be over 2,000 feet in thickness, however.

Description. The Blairmore formation may be divided into two members. The lower, about 630 feet thick, consists of grey sandstones, shales and limestones, with conglomerate at the base. The upper and thicker member consists of sandstones, shales, arkoses, conglomeratic lenses and volcanic tuffs at the top, which generally show a pronounced green coloration.

The lower member more closely resembles the Kootenay formation than the upper Blairmore. Its colors are sombre and the grain size is generally fine. At its base is a conglomerate, referred to as the basal Blairmore conglomerate. Above this lie thin sandstones, dark grey shales and dark blue-grey freshwater limestones. The following section was measured on Picklejar creek:

Overlying beds, greenish pebble conglomerate of upper member of Blairmore formation.
Conformable contact.

Lower Blairmore:	
Shale and shaly sandstone, largely concealed	57 feet
Freshwater limestone, light grey weathering, dark grey, with pyrite at base, and poorly preserved gastropods and plants. Shaly towards top	34 feet
Interbedded dark grey to light grey, rubbly-weathering shales, sandy shales and fine, hard, light grey quartzitic sandstone, becoming slightly greenish towards top	450 feet
Fine, brownish to light grey, thin-bedded sandstone, with a few scattered quartzite pebbles up to one inch in diameter	24 feet
Hard, fine grained quartzitic sandstone and siliceous, light to dark grey shales	41 feet
Very fine, very hard, buff-weathering, quartzitic sandstone, with lenses of coarse sandstone and pebbles	11 feet
Fine to coarse, light grey, cherty sandstone	6 feet
Conglomerate, with black and grey chert and argillite pebbles averaging one-quarter inch in diameter, but up to one inch, in black, hard, medium grained sandstone; becomes a very coarse sandstone at top	14 feet
Total thickness of Lower Blairmore	637 feet

Underlying beds, Kootenay formation.

At this locality, the basal conglomerate is not typically developed. The basal Blairmore conglomerate is recognizable throughout the area, although two distinct phases are present. In the southern part of the area the basal conglomerate is similar to the basal bed reported from other areas in southern Alberta. It consists of a bed averaging twenty feet in thickness, but varying from fifteen to thirty feet. The bed is sometimes conglomeratic throughout. At other times lenses of coarse white crossbedded sandstone occur. The pebbles consist of white, green, grey and black chert, argillite and quartzite. These average about one inch in diameter, and seldom exceed one and one-half inches. The pebbles are well-rounded but tend to be somewhat flattened. The matrix consists of light grey sandstone. The rock is very well consolidated. Joints cut across pebbles and matrix alike. The conglomerate weathers to a light grey but is frequently coated by lichens which give the outcrop a dark appearance from a distance. The conglomerate rests upon the eroded surface of the Kootenay formation and upwards usually passes into a coarse sandstone or directly into the finer beds of the lower Blairmore.

North and west of Lineham creek there is a pronounced change in the character of the basal beds. Immediately north of Lineham creek, the following section was observed:

Overlying beds, lower Blairmore	
Conglomerate, resembles the typical basal conglomerate in all respects	25 feet
Sandy shale, and fine quartzitic sandstone, typically Blairmore	15 feet
Conglomerate, dark grey, very fine matrix, with black and dark grey chert and argillite pebbles averaging one-quarter inch in diameter	4 feet
Underlying beds, Kootenay formation	

The beds between the two conglomerates are of a typical lower Blairmore character, particularly the fine quartzitic sandstones, which were never observed at any place in the Kootenay. The lower conglomerate is extensive in the northern part of the area, much more extensive than any coarse phase in the Kootenay. For these reasons, the lower conglomerate and the beds above it are included in the Blairmore formation. Northwards from Lineham creek the upper conglomerate lenses out within one mile. On Picklejar creek the lenses of pebbles about ten feet above the fine conglomerate at the base are believed to represent the upper band. Farther north the upper band becomes stronger and is present throughout the area. It tends to be coarser than the basal conglomerate of the southern part of the area and on Storm creek contains white quartzite pebbles up to four inches in diameter. The coarseness, continuity and common green and abundant white pebbles serve to distinguish this band. The lower bed is much more variable in thickness than the upper and is frequently absent altogether. Its maximum development was observed on the west limb of the Highwood valley syncline, east of Mist mountain, where it consists of thirty feet of coarse dark grey, crossbedded sandstone with lenses of dark chert and argillite

pebbles. It is present in some exposures west of Mist creek and Sheep river, and absent in others. It occurs on Bishop creek where it is a little coarser. It was also seen on Storm creek. Within the area of its occurrence, it may be locally absent, in which case the sandstones and limestones that occur between it and the upper conglomerate, serve to delimit the formation. The lower conglomerate is characterized by the fine grain of the matrix, the dark color of the rock and of the pebbles, and the complete absence of white quartzite and green chert pebbles. The interval between these two conglomerates varies from fifteen feet at the south, to about fifty feet towards the north. It appears to be greater on Storm creek but no measurements are available.

The most characteristic beds of the lower Blairmore, exclusive of these conglomerates, consist of very fine quartzitic sandstone and dark blue-grey freshwater limestone.

The quartzitic sandstones are generally light grey in color and occur in beds up to eight inches in thickness. They are very hard and very fine-grained, cemented by silica. They frequently weather buff. On dip slopes the upper surfaces of these beds tend to weather into upraised mammillary forms about an inch in diameter. These forms are bounded by straight edges which probably represent joints recemented by silica. The general appearance is close to that of the full comb of a wasp's nest.

Freshwater limestones are of irregular occurrence in the lower Blairmore and may occur anywhere within it. The limestone may

occur either as large well-bedded lenses, or as small, discontinuous nodular layers. The color is always a dark to very dark bluish grey. Frequently parts of the limestones are coquinal. They may occur between the lower and upper conglomerate or anywhere else in the section.

A two-inch coal seam, with associated carbonaceous shale, was found about seventy-five feet above the base, on Bishop creek.

A two-foot bed of dark grey, rather fissile shale, carrying marine pelecypods, was found 570 feet above the base of the member on Highwood river, about one mile below the mouth of Cat creek.

The upper member of the Blairmore formation consists of greenish shales, sandy shales, sandstones and arkoses, with tuffs in the upper part. On Picklejar creek the base of the member was drawn at the base of a thirty-one foot bed of olive-green sandstone with lenses of pebble conglomerate. This sandstone is not readily recognized, but appears to be present throughout the area. Above it green sandy shales and sandstones occur. About fifty feet above this sand, chocolate-brown weathering, grey to green sandy limestone nodules and lenticular beds occur. These persist through most of the formation but are absent in the upper five hundred feet or so.

Lenses of pebble conglomerate are of fairly frequent occurrence in the upper Blairmore. These usually consist of chert and quartzite pebbles, but at two locations beds containing igneous

pebbles were found. About two miles northwest of Lineham creek, a two-foot bed was found which carries pebbles of chert, quartzite, feldspar porphyry, scarce granite and very rare dark grey limestone resembling some of the Paleozoic limestones of the Rocky Mountains. The pebbles average one inch in diameter and reach a maximum size of two inches. These are well rounded. The matrix is a dark green, fine grained sandstone. Stratigraphically it lies about 1,500 feet above the base of the Blairmore formation.

On Bishop creek another pebble bed was found. Its stratigraphic position is not known, but it probably occurs in a somewhat similar horizon to the other. It consists of a grey-green sandstone with small pebbles scattered along the bedding planes. Green shale pebbles are very abundant. The pebbles consist of various colored feldspar porphyries with a few pebbles of chert.

The most outstanding marker in the upper Blairmore is a zone of fairly coarse arkose, the surface of which weathers to a peculiar rough texture. The color is brownish to greenish-brown. It lies about 600 feet below the top of the formation. It is fairly frequently exposed. The best exposure is immediately north of Highwood river, in section 11, township 17, range 6, west of the 5th meridian, where the following section was measured:

Top not exposed

Chocolate-brown weathering, light grey, calcareous arkose . .	4 feet
Poorly exposed, light grey weathering, medium to coarse grained, brown-grey arkose	55 feet
Buff weathering, brown, coarse, massive, soft arkose with rare chert pebbles up to one-third inch at base and white quartzite pebbles at top	5 feet

Coarse, thin-bedded, greenish to grey-brown arkose, very hard and with clay pellets at base.	2 feet
Coarse, soft, buff-weathering, grey-brown arkose, with white and green clay pellets at base	7 feet
Fine grained, grey-brown, arkosic sandstone, finely banded with very thin dark layers	6 feet
Total thickness exposed	79 feet
Base not exposed	

This bed carries abundant small, well-formed feldspar crystals, which must have originated fairly close to the site of deposition. It is believed that it is derived from the Crowsnest Volcanics, either as a crystal tuff or by erosion of the volcanic series. A somewhat similar bed was reported by Beach (1943, p.40), in the Moose Mountain area, but there it is only two to five feet thick.

The uppermost beds of the Blairmore formation are tuffaceous, related to the Crowsnest Volcanics. These extend downwards at least two hundred feet and probably extend much farther. The beds vary from very fine dense, dark green tuffs, to light grey-green, soft beds that resemble a fine sandstone in the hand specimen. The individual beds rarely exceed three feet in thickness. At least part of the tuffs are marine, as a limestone carrying a marine fauna was found to contain considerable devitrified glass.

The finer grained beds near the top of the Blairmore frequently weather to a light pink, which shows up sharply in outcrops. Some beds are dark red to maroon on fresh surfaces, sometimes are red mottled with green. These colored beds usually occur near the top of the formation and form a fairly reliable marker.

At several localities on Mist creek and at one locality south of Storm creek, the top of the Blairmore is marked by a thin conglomerate of chert and quartzite pebbles in a hard green matrix. These beds are believed to be part of the Blairmore formation because of their resemblance to other pebble lenses lower in the section.

Age and Correlation. The fossils collected from the Blairmore formation were all either undescribed forms or were too poorly preserved to identify.

Two small faunas were collected from the lower member of the Blairmore. The lower of these was collected from a limestone band about 300 feet above the base, on the east side of Highwood valley, about one mile northwest of Lineham creek. The fauna is non-marine and contained the following forms:

Silicified sponge spicules ?
Unio ? sp.
Patula ? sp.
Campeloma ? sp.
Fish bone
Chara-like forms

This zone, the fauna of which is largely undescribed, is quite widespread in the lower Blairmore*.

A bed of dark grey shale, about 570 feet above the base of the Blairmore, was found on Highwood river about a mile downstream from the mouth of Cat creek. This bed contains the following forms:

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*Dr. P. S. Warren, personal communication.

Inoceramus sp. or Aucella sp.
Tellina sp.
Corbula or Unio sp.

This small fauna indicates that marine or non-marine conditions existed in the Highwood-Elbow area during part of Lower Blairmore time.

A fauna was collected from the upper Blairmore on the ridge between Storm and Odlum creeks, from chocolate-brown weathering limestone lenses. Microscopical examination showed the presence of volcanic glass. The following forms were collected:

Grammatodon ? sp.
Astarte ? sp.
Ammonite ? unidentifiable

Dr. Warren states that this fauna is undoubtedly marine*.

The Blairmore formation is correlated with the Blairmore of the Crowsnest Pass on its stratigraphic position and lithological character. MacKay (1932, p. 22) describes the Blairmore as follows:

"The Blairmore formation overlies the Kootenay. It consists of massive, crumbly, sandy shales of various colors, including green, grey, brown, red and black, interbedded with minor amounts of massive, soft, greenish-grey, coarse-grained and shaly sandstones. There are occasional thin beds of ironstone and at least one rather persistent bed, 10 to 15 feet thick, of bluish grey, shaly limestone which in places is fossiliferous . . . . The base of the formation is marked by a massive bed of cherty conglomerate or coarse cherty sandstone. . . . . designated the Blairmore conglomerate."

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*Dr. P. S. Warren, personal communication.

This description,with but slight modification, could be applied to the Blairmore beds of the Highwood-Elbow area.

The Blairmore in the Crowsnest Pass contains two floras (McLearn, 1945, p. 8), the lower of which has been dated Aptian, while the upper is Albian (Bell, 1945, p. 11). Both are Lower Cretaceous. The floral change does not correspond to the lithologic break between the lower and upper Blairmore members, as used by the writer. The Aptian flora ranges through the lower two-thirds of the Blairmore formation in the Crowsnest Pass (McLearn, 1929, p.104).

The Crowsnest Volcanics in the Crowsnest Pass overlie Blairmore beds carrying an Albian flora, so that the volcanics must either be late Albian or early Upper Cretaceous. In the Highwood-Elbow area, the principal tuffs occur interbedded with typical Blairmore sediments. Hence, the lower part of the volcanics is probably Albian. The discovery of volcanic glass associated with a marine fauna in the Blairmore, means that this fauna is probably late Albian. If so, it will correlate to the north with the upper part of the Mountain Park formation, much of which is marine*, and with some part of the Fort St. John group.

Yarwood (1931, p. 147) records marine fish scales from a zone in the Lower Cretaceous of the Spring Coulee well in southern Alberta, in a 90 foot zone starting 37 feet above the base. This

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*C. R. Stelck, personal communication.

marine horizon may correspond to the marine horizon in the lower member of the Blairmore.

Lower Alberta Formation

Name. The dark marine shales of southwest Alberta were referred to the "Benton" by Stewart (1919, p. 30). Rutherford subdivided these on Bow river into Upper and Lower Benton formations, separated by the Cardium (1927, p. 24-29). They have also been referred to the Colorado. As the series does not correlate with the Coloradoan exactly, Hume (1929, p. 6) proposed that the term Alberta shale, divisible into Upper and Lower and separated by the Cardium sandstone, be applied to these beds in southwestern Alberta. This has since been followed by the Geological Survey of Canada.

Distribution. The Lower Alberta formation is of restricted occurrence in the area. The most extensive outcrop extends from about one mile above the mouth of McPhail creek to the east side of Misty range, as a narrow band of beds occupying the trough of a syncline. Two narrow bands occur on Baril creek but both are faulted out south of Highwood river. Another band, of unknown lateral extent, outcrops on the ridge between Storm creek and Odlum creek.

Thickness. Only the lower part of the formation has so far been found in the area and it is probable that no more than 600 feet of beds are present in any of the occurrences.

Description. The Lower Alberta formation consists of dark grey shales, thin fine grained sandstones, silty limestones and lenses of coarse pebbly sandstone.

The Lower Alberta formation overlies the Blairmore formation with a sharp contact (see Plate X A). A few chert pebbles, about one-eighth of an inch in diameter, usually occur in the lowermost six inches of shale. A six to eight inch bed of conglomerate, with a very dark matrix, occurs at the base of the westernmost of the two bands crossing Baril creek. A certain amount of erosion has probably taken place.

The shales at the base of the formation are very fissile and flaky, dark grey in color and frequently stained brown by iron oxide. Upwards, the shales become sandier and a little lighter in color. Interbedded with these are thin silty sandstones and silty limestone, both of which weather to a buff or yellow, but are dark grey on fresh surfaces. Some of the sandstones are highly micaceous. Fucoid markings are sometimes abundant on these silty sandstones.

In the lower forty feet of the formation, lenses of fairly coarse, light grey sandstone, sometimes carrying well-worn pebbles of chert, quartzite and coal, occur. It is thought that these lenses correspond to the "grit bed" of the eastern foothills.

About two hundred feet above the base of the formation is a horizon marked by one or more beds of white to orange clay shales, which somewhat resemble bentonite. The best exposed

section occurs on the east bank of Highwood river, about three-quarters of a mile above the mouth of Bishop creek. The following section of this horizon was measured:

Overlying beds, dark grey sandy shale	
White clay shale	0.5 feet
Orange-yellow clay shale, very micaceous, party cemented with calcite	0.6 feet
White clay-shale	1.1 feet
Dark grey sandy shale	9.5 feet
White clay-shale	0.2 feet
Dark grey fissile shale	0.4 feet
Dark grey to white clay shale	0.1 feet
Rusty weathering, dark grey shale	0.4 feet
White clay shale	0.05 feet
Dark grey shale	12.5 feet
White clay shale	0.3 feet
Dark grey sandy shales and thin sandstones.	

These beds are very apt to be confused with bentonite in the field, as they become very greasy when wet, but no swelling occurs when immersed in water. The beds are frequently very rich in biotite crystals. This rock is probably a decomposed tuff, derived either directly or by erosion from the Crowsnest Volcanics.

Age and Correlation. The lower two hundred feet of the formation appear to be barren of fossils except fish scales. About two hundred feet above the base *Inoceramus labiatus* Schlotheim is of common occurrence. About four hundred feet above the base, the following fauna was collected from a limestone lense on the east bank of Highwood river, a few hundred feet above the mouth of Odlum creek:

Inoceramus sp.
Pelecypod unidentifiable
Prionotropis woolgari (Mantell)
Exiteloceras cf. *pariense* (White)
Scaphites sp. nov.
Fish scales

These fossils are all indicative of Lower Turonian time (Reeside, 1924, p. 28). In United States they occur in the lower part of the Coloradoan.

In Alberta the Coloradoan has been zoned (Webb and Hertlein, 1934; Warren and Rutherford, 1928; McLearn, 1937) several times. The writer's findings agree with the zoning in that there is a "barren zone" with fish scales at the base, an Inoceramus labiatus zone above, with a Prionotropis zone above that. The fossils listed above definitely correlate these beds with the Lower Alberta shale, part of the Blackstone formation and part of the Lower Smoky River shale, of Upper Cretaceous (Turonian) age.

GLACIAL AND RECENT

Deposits of Glacial and Recent age occur widely in the area, as a thin mantle on top of the bedrock.

Glacial deposits were recognized only in the vicinity of Elbow river. Both to the north and the south, the tops of some of the ridges extending east from Misty range are capped by an unknown thickness of boulder clay, with abundant large boulders derived from Paleozoic limestones. A few erratics occur in other parts of the area. The largest of these is a block of basal Blairmore conglomerate about six feet by six feet by eight feet, which lies on top of the ridge west of Cat creek, at an elevation of about 6,900 feet. This is almost 1,000 feet above the highest outcrops of the conglomerate, south of Mist creek.

Post-glacial deposits are much more widespread. Terraces along the Highwood river consist of gravels made up of pebbles and boulders of Paleozoic and Mesozoic rocks, although the Paleozoic materials predominate. At the mouth of Cat creek, about forty feet of bedded gravels are exposed. An unknown thickness occurs near the mouth of Stony creek, obscuring most of the bedrock between the Sentinel Ranger Station and Mt. Head. Up to one hundred feet of waterlaid gravel occurs in Lineham Creek basin and lesser thicknesses occur in Picklejar and other nearby streams.

Calcareous tufa is being deposited by several small springs in the area. These deposits are all superficial. The most extensive occurs on the south bank of Highwood river, about three-quarters of a mile below the mouth of Cat creek.

Travertine, deposited in some of the gravels near Lineham creek, has cemented them into a weak conglomerate.

Plate VII. North side of ridge extending east of Mist mountain, showing Lower Alberta formation (LA) in the trough of the Highwood valley syncline. P, Paleozoic; SR, Spray River; F, Fernie; K, Kootenay; B, Blairmore.

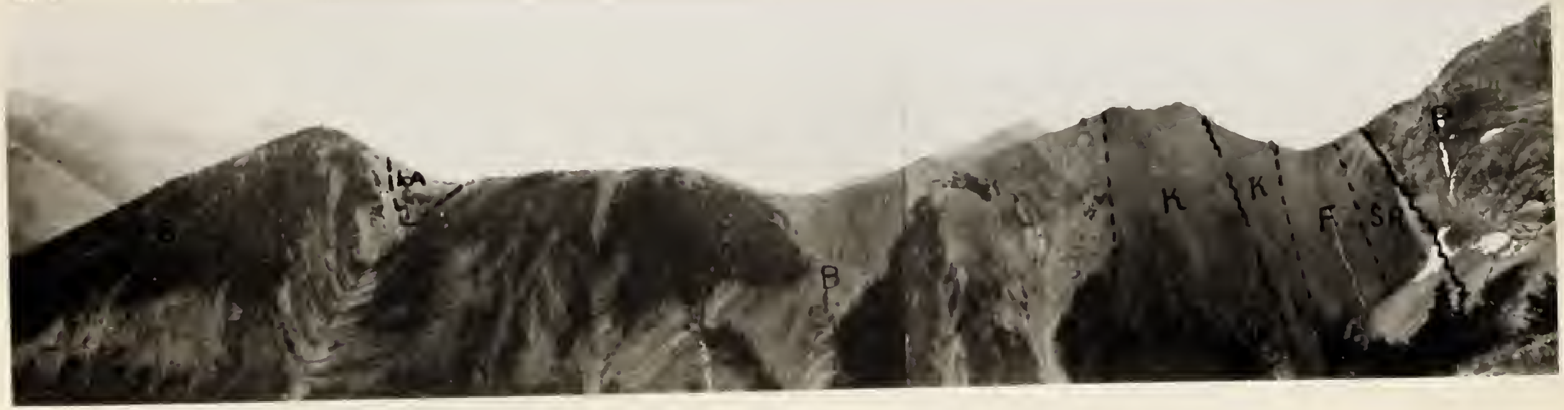

B
K
K
F
SA
P

Plate VIII. North side of ridge at headwaters of Mist creek, showing folding and faulting of beds east of Misty range.

A. Sketch of ridge by G. M. Dawson (Dawson, 1886, Figure 5, page 100).

B. Photograph of ridge. P, Paleozoic; F, Fernie; K, Kootenay; B, Blairmore. (Photograph courtesy Dr. J. A. Allan).

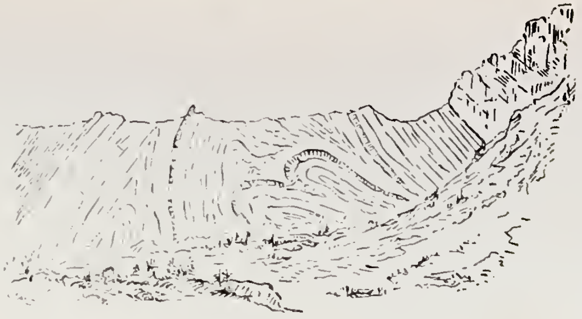
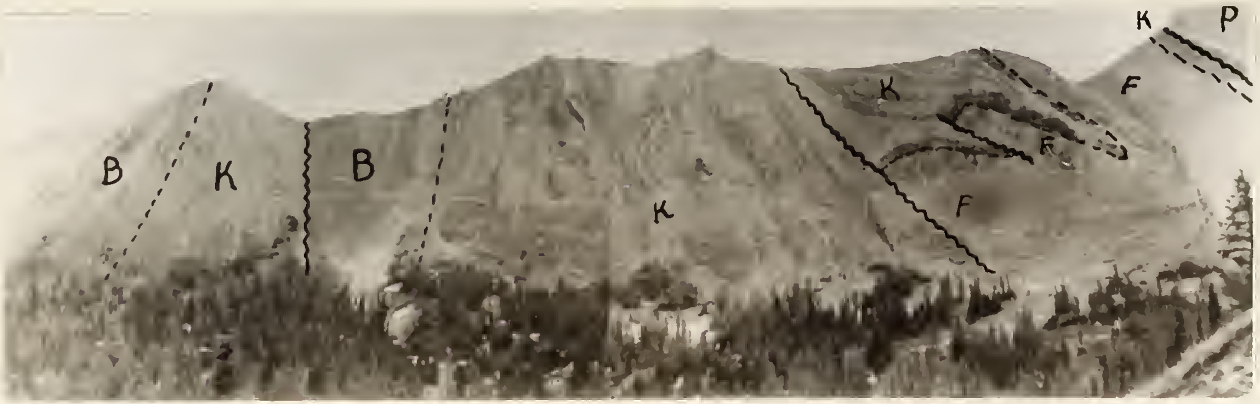


FIG. 5. OVERTURNED FOLDS OF CRETACEOUS ROCKS AT JUNCTION WITH LIMESTONE, MIST CREEK.

A

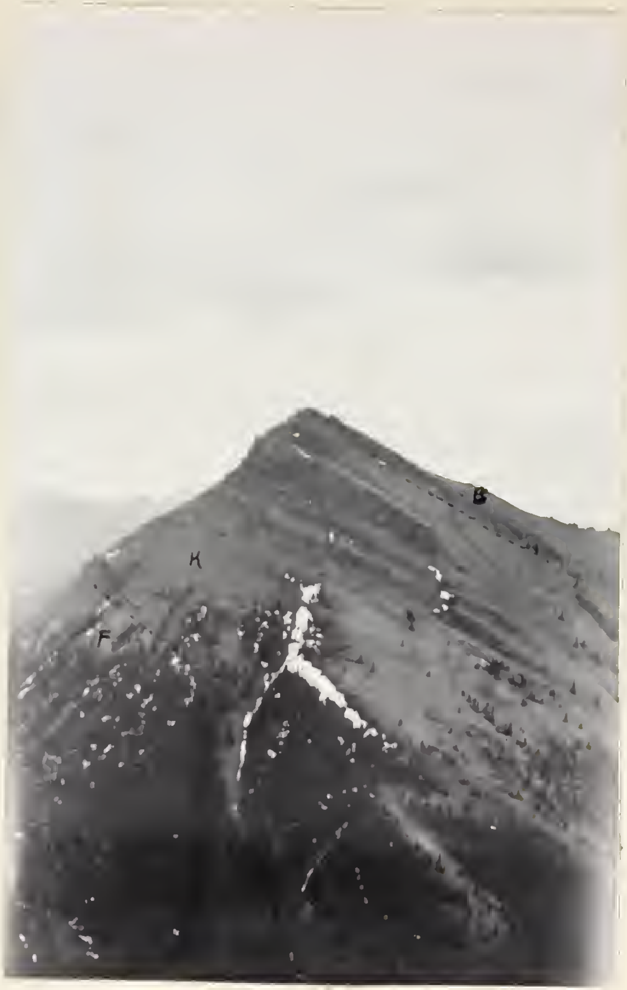


B

Plate IX. A. Erosional contact of Spray River formation on Paleozoic beds, in section 7, township 17, range 5, west of 5th meridian. Hammer handle one foot long.

B. Upper Fernie (F), Kootenay (K), and lowermost Blairmore beds (B), exposed in Zone A, two miles northwest of Sentinel Ranger Station.

A



B

Plate X. A. Contact of Lower Alberta formation (dark beds on left) on Blairmore formation. Highwood river, downstream from mouth of Odlum creek. (Photograph courtesy Dr. J. A. Allan).

B. Large ferruginous limestone concretion in Fernie formation, exposed southeast of Mist mountain. Hammer handle one foot long.

A

B

Chapter V. STRUCTURAL GEOLOGY

GENERAL STATEMENT

The Highwood-Elbow area lies within the Rocky Mountains. Due to the generally incompetent nature of the Mesozoic rocks, these beds are more highly disturbed than the competent limestones of Paleozoic age.

The strata of this area are generally south-plunging, bringing older rocks to the surface to the north. On the south, the area is continuous with the Crowsnest basin (Rose, 1919, 1921). To the north, the south plunge, combined with faulting, finally brings Paleozoic rocks to the surface over the entire width of the basin, thus cutting off the Mesozoic strata of the Highwood-Elbow area from those of the southern extension of the Cascade basin.

The Mesozoic beds differ from one another in their competency. The hard sandstones and conglomerate of the upper Kootenay and lower Blairmore are the most competent in the area. The rest of the section, largely shales, has suffered considerable folding.

The general strike in the area is N 20° W, with small deviations due to local structural conditions. The beds generally dip fairly steeply westwards. There is one major fold, the Highwood valley syncline. West-dipping thrust faults control most of the structural features.

The most intense deformation has occurred in a small area north of Sentinel Ranger Station and about the south and east sides of Misty range.

For purposes of discussion, the Highwood valley syncline makes a convenient dividing line between the structures of the eastern and western parts of the area.

HIGHWOOD VALLEY SYNCLINE

This is the most marked fold in the area. It was traced from near the mouth of McPhail creek to the north side of Rae creek, and possibly extends north of Elbow river. The dips are high on both limbs and the western limb frequently shows overturning east of Misty range. At the south end, dips are very high and the fold is almost isoclinal. The axis appears to plunge north to the vicinity of Picklejar creek. There, the plunge is reversed and is southwards as far as the structure could be traced to the north. The southwards plunge amounts to about five degrees. This was calculated from the distance between the outcrops of the base and top of the Blairmore formation along the synclinal axis, east of Misty range. From the southernmost ridge east of Mist mountain, to within a mile of McPhail creek, a narrow band of Lower Alberta shale lies along the axis. To the north and south, Blairmore beds occupy the centre, while farther north Kootenay and Fernie strata occur.

To the east of Misty range, two almost vertical faults,

one on each side of the axis of the syncline, occur. The central part of the syncline has been faulted upwards with respect to the limbs, like a grape squeezed out of its skin. The beds beyond these faults also dip towards the axis of the syncline, maintaining the synclinal structure. The west limb of the syncline is truncated by a thrust fault which will be described later.

Minor folding has occurred on both limbs. This is most pronounced east of Misty range and near the mouth of McPhail creek.

STRUCTURE EAST OF THE SYNCLINE

East of the Highwood valley syncline, the strata generally dip west, with a few minor reversals, but cut by three major thrust faults.

The most easterly thrust, which will be referred to as the First Fault, was first recognized in section 32, township 16, range 5, west of the 5th meridian. Here the fault cuts the basal Blairmore conglomerate. The displacement is so small that drag folding has nullified the stratigraphic displacement at the surface. The strike to the south and west of the First Fault swings around to almost east-west, with dips to the south. Northwards, the displacement along the fault becomes greater. The beds both above and below the fault dip towards the southwest, so that lower beds are brought rapidly to the surface. About three miles north of where this fault was first recognized, Paleozoic beds are thrust up onto

Spray River and Fernie strata. Probably due to drag along the fault, these lower Mesozoic beds have been folded into a small syncline. The most remarkable feature of the structure is the strong south plunge of the fault block, which causes the strike of the Mesozoic beds on the west flank to swing almost to an east-west strike. Towards the northern end the fault trace lies on a high ridge and swings towards the east. This shows that the fault plane dips to the west; apparently not very steeply. It is possible, however, that the strike of the fault changes as Paleozoic beds become involved. South of Highwood river a small terrace structure occurs on the east bank of Etherington creek, on strike with the First Fault, and may be a reflection of that structure.

The Second Fault lies about three-quarters of a mile west of the First Fault. It was found on Baril creek, with Blairmore strata thrust on Lower Alberta. A thousand feet north, Kootenay beds are brought to the surface along the fault, and the Lower Alberta is cut out. The fault was traced northwards. A mile south of Cat creek, the Blairmore formation is cut out and at almost the same place, basal Kootenay and upper Fernie beds are brought to the surface. This fault was traced to the north side of Lineham creek basin. The last Kootenay strata are lost in the valley of Lineham creek, while the Fernie and Spray River formations are lost on the north side of that valley. (See Plate VI B). The dip of the fault plane is to the west, at an angle of about 45°, from the trace of the fault as mapped through Cat creek valley.

What is believed to be a single fault extends from Baril creek to north of Elbow river. It was not traced continuously, as there is a gap in the mapping between Baril creek and the Highwood, while towards the north end, in Sheep River valley, recent deposits conceal its trace. If not continuous, it at least represents a series of thrust faults, arranged linearly along their strike. The fault, as mapped by Rose (G.S.C. 1924), does not extend from the Highwood all the way to Baril creek, but is absent over an interval of about one mile. To the north, however, the writer traced the fault from Highwood river to the edge of Sheep River valley. On Baril creek Kootenay strata are faulted on the Lower Alberta formation. On Cat creek a few feet of the lower Blairmore are present below the fault, but these pinch out a few hundred feet north. Fernie beds first appear above the fault in drag folds on the south edge of Lineham Creek valley. The upper part of the Fernie formation is present at the surface, above the fault, all the way to the upper part of Mist creek, where the Fernie beds disappear and strata are faulted on Kootenay. The Fernie reappears in Burns creek. The Kootenay is lost in Sheep River valley. At the north, Paleozoic beds are faulted on lower Mesozoic and upper Paleozoic strata; north of Elbow river the fault dies out in a ridge of Paleozoic rocks. The dip of the fault plane of the Third Fault is to the west. The straight trace of the fault indicates a high dip, probably over 60°.

A small fault was observed on Baril creek, east of the Second Fault. No trace of this structure was found north of

Highwood river.

Minor faulting has probably taken place throughout much of the area, especially in the shaly parts of the succession of beds. The Fernie formation is especially susceptible to this and frequently shows thickening, largely due to minor faulting.

There are several small transverse faults in the eastern part of the area. With one exception, the apparent downthrow side is to the north. Most of these faults are too small to map.

The most southerly oblique fault occurs in section 5, township 17, range 5, west of the 5th meridian. The base of the Kootenay formation is displaced about one hundred feet vertically, with the downthrow to the south. No displacement of the upper Kootenay beds was observed at this locality (see Plate XI).

Two small transverse faults, displacing the basal Blairmore conglomerate, occur in the southwestern corner of section 6, township 17, range 5, west of the 5th meridian (see Plate VI A). The strike of the faults appears to be almost due north, but erosion may have removed part of the conglomerate. The horizontal distance from one outcrop to another along the apparent strike of the faults, is about three hundred feet. The west side has been downthrown with respect to the east side. The conglomerate here dips about 70° to the southwest. Another transverse fault may occur in the northeast corner of the same section, as the base of the Blairmore formation is slightly out of alignment. The displacement along these faults has been small and they are probably of limited extent. However,

other faults of the same type may be expected in the Kootenay strata in the vicinity.

The largest transverse fault in the area occurs on the west flank of Highwood range at the headwaters of Sheep river. Horizontal displacement is over five hundred feet. Vertical displacement is at least three hundred feet, as the Fernie-Spray River contact on the north side of the fault is brought almost exactly into line with Spray-River-Paleozoic contact on the south side of the fault. The strike of the trace of the fault is N 55° E. The northwestern side has been downthrown. The direction and amount of dip are unknown. Brecciation of the Paleozoic limestones has occurred close to the fault, while close jointing has occurred farther away. Slight drag folding suggests that the movement along the fault was parallel to the dip, perpendicular to the strike, but the evidence is insufficient to be certain.

These small faults are interpreted as tensional, induced by stresses set up by the southwards plunge of the basin. In most cases, these will be of limited extent, but may interfere somewhat with mining operations.

Mount Head lies north of Sentinel Ranger Station, as the south end of a high ridge. The small areato the south of Mount Head has been badly broken. The structure isnot clear to the writer. On the east side of Mount Head, the Paleozoics appear to be in folded relationship with the next ridge of Paleozoic rocks to the east. On the west the strike, coming about the south end of

the mountain swings from N 25° W to N 60° W, and on the south face some beds strike east and west. The Spray River and Fernie formations make a pronounced swing to the east, about the south end of the mountain. There is thus a suggestion of a very steeply plunging anticline. However, the south-dipping beds on the south end of the mountain are not thick enough, stratigraphically, to support this idea. There is a possibility of a transverse fault occurring here, but such a fault would have a very large displacement and would be expected to show up in the Kootenay beds a short distance to the west. Crumpling and minor faulting occur in the Mesozoic beds at the south end of the mountain. The question is still open, but at the present time the writer is more in favor of the idea of a transverse fault.

A small anticlinal fold, with the steep limb to the east, brings Spray River beds to the surface west of Stony creek, three-quarters of a mile to the north of Highwood river. This fold may continue north as the small fold in section 18, township 17, range 5, west of the 5th meridian. On the south side of the Highwood, this anticline was not observed, but upper Fernie beds show a synclinal structure to the east of the strike of the anticline and it is assumed to pass across the Highwood river.

The largest fold east of the Highwood valley syncline occurs in upper Kootenay beds west of the Second Fault. A reversal of dip produces a small anticline and syncline, which were traced from Highwood river to Cat creek. The magnitude of these folds is

not great. The distance from the west dipping beds on the anticline, to the west-dipping beds on the east limb of the syncline, is only five hundred feet horizontally.

Some folding has occurred in the Blairmore strata, east of the mouth of McPhail creek. This appears to die out to the north.

The Kootenay strata both above and below the Third Fault, on the ridge west of Cat creek, show considerable drag folding, but farther north, most of this folding is taken up by the Fernie strata above the fault.

In the vicinity of Burns Mine, the Kootenay strata above the Second and the Third Faults are tightly folded. These folds are asymmetric, with the axial planes dipping to the west. This folding is especially marked in the lower beds of the Kootenay above the Third Fault, and is believed to indicate subsidiary movement in the fault block. These folds become less numerous and slightly larger between Burns and Rae creeks, but are too small to map.

North of the transverse fault at the headwaters of Sheep river is a small, south-plunging syncline, involving Fernie, Spray River and Paleozoic beds. The south end is cut off by the transverse fault. It is not known if it extends south of this fault, due to lack of exposures. Dips are quite low. The western limb of the southern part of this fold is reversed in a sharp anticline which passes into a fault northwards. This fault brings Paleozoic beds on the east against Paleozoic, Spray River and Fernie beds on

the west. The downthrow side is to the west. The strike and dip of the fault plane are unknown. Between this fault and the Third Fault, Spray River and Paleozoic beds show a gentle dip towards the south and apparently represent the west limb of this small syncline.

The Kootenay strata west of the Third Fault, forming the eastern limb of the Highwood valley syncline, usually dip from 70° to 90° to the west. However, in a zone extending from two miles north of Lineham creek to one mile north of Picklejar creek, these beds are overturned and show dips up to 148° to the west. These overturned beds are seen only on the ridge which the Kootenay formation forms. In the creeks cutting through the ridge, the dips of the Kootenay strata are about 90° to the west. There are two explanations which have occurred to the writer. This structure commences to the east of the south end of the disturbed zone which culminates in Misty range. The writer first considered that the Highwood valley syncline might have been converted to a fan-fold with both limbs overturned. However, the west limb in this part of the area is dipping normally east. Further, the transmission of stresses to the east limb would be difficult. Farther north, where the uplift of the Misty range is great, the beds on the east limb of the syncline are dipping normally westwards. This idea was abandoned.

A second hypothesis is developed below. The beds are overturned only on the sides of the ridges. In the creek valleys dips are 80° to 90° west. The Blairmore conglomerate lies low on

the hillside. To the north, the dip of the Kootenay beds decreases to about 65° to 75° to the west. To the south, the hard basal Blairmore conglomerate usually occurs high up the side of the ridges. The Kootenay sandstones are locally not massive. At the extreme top of the ridge the beds are vertical. There are thus localized conditions which would be favorable to rock creep. The writer believes that this explanation fits the observed facts. Creep would be largely inoperative farther north where the dip of the beds is lower. Farther south the Blairmore conglomerate possibly acts as a retaining wall, inhibiting creep.

STRUCTURE WEST OF THE SYNCLINE

The main structural features west of the Highwood valley syncline are related to the Misty range uplift. The farthest south that this disturbance was mapped was on Bishop creek, where a reversal of dip on the west limb of the syncline results in an anticlinal fold. Dips on the west limb average 70° to the west, while on the east limb they reach 90° to the east. The structure was traced almost to Storm creek. At the northern end, the dips on the west limb are about 45° west, while the east limb still shows very high dips. The west limb is interrupted by a fault, with the downthrow side to the east. Both the fold and the fault bring Kootenay beds to the surface on Bishop creek.

North of Odlum creek, the Blairmore and Kootenay strata are badly crumpled. Lower Kootenay beds are thrust on upper Kootenay strata by the fault on the west limb of the anticline.

These lower Kootenay beds are closely folded. To the west, what appears to be an east-dipping thrust fault brings Kootenay beds over the east limb of a small syncline of Blairmore strata. West of the syncline, Kootenay beds are exposed by a small anticline, which is faulted on the west, causing repetition of about one hundred feet of upper Kootenay and lower Blairmore strata.

This highly disturbed zone is generally anticlinal, with the stratigraphically lowest beds exposed at almost the highest elevation. These lower Kootenay beds, however, appear to represent a small horst, forced up between inwards-dipping thrust faults. The general anticlinal structure is also shown by the strikes, which swing close to east-west, with south dips. Misty range comes up about two miles north of this highly disturbed area and on strike with it. This structure is definitely associated with the Misty Range uplift.

West of this disturbed area, Blairmore beds, somewhat folded, outcrop. Faulting of the Blairmore section may have occurred. Details of this part of the area were not worked out in the field, but there are indications of considerable deformation. To the west of the Blairmore formation is a narrow band of Lower Alberta shale, on which is faulted more Blairmore beds. These are cut off to the west by a thrust fault which underlies the High Rock range, and brings Paleozoic beds onto Blairmore formation.

The High Rock range thrust was poorly exposed where seen, but appears to be dipping west at about 70°. Twenty feet of beds below it have been brecciated.

Northwards, the Mesozoic beds split about Misty range, one band extending north along the east side and the other along the west. The band on the western side was not examined in detail. The strata are closely folded immediately west of Mist mountain. A small fault occurs in the Fernie formation but northwards, within about two miles, brings up Paleozoic beds on Lower Spray River and then Paleozoic strata. The Kootenay formation is closely folded. Northwards, towards Pocaterra creek the deformation appears to be less intense.

The eastern band properly includes the west limb of the Highwood valley syncline, and the fault accompanying it. The strata are closely folded (see plates VII and VIII). The west limit of the Mesozoic beds is the thrust fault underlying Misty range. This fault surface is exposed at the head of Mist creek and shows a dip there of 60° to the west. Underlying the thrust are eight inches of black, carbonaceous, sandy gouge, with a few angular fragments of sandstone and limestone in it. The Misty Range fault may be followed north to the Little Elbow, bringing Paleozoic strata up on Fernie or lower Kootenay beds. North, a subsidiary fault brings up Paleozoic limestones beneath the Misty Range thrust.

Truncating the western limb of the Highwood valley syncline is a thrust fault which brings up Fernie and Lower Kootenay beds on the upper Kootenay of the syncline. (See Plate VIII). This fault was lost north of Rae creek, due to a thick cover of

drift and appears to be absent north of Elbow river. The beds between this structure and the Misty Range fault are folded in an anticline. Higher beds are involved farther north and no Fernie was found below the Misty Range thrust, north of the Elbow.

The structure at the south end of Mist mountain is not yet understood, but a preliminary discussion is given here for completeness.

A narrow ridge, composed of Paleozoic beds, extends southwards from Mist mountain proper. On the east side, the beds forming this ridge are east dipping with Spray River, Fernie and Kootenay strata in the proper order to the east, although these have been thinned, either by flowage or faulting. If these east-dipping Paleozoic beds are followed north, to the east side of Mist mountain, they appear to lie east of Misty Range fault. If the eastern side of the ridge is followed south, the beds turn partly around the end of the ridge, like asteeply-plunging anticline. On the west side of the ridge, the beds are dipping west and some of them can be followed around to the east side. At the southwest corner of the ridge, however, the Spray River-Paleozoic contact on the west appears to swing in towards the axis of the structure, north of the Spray River-Paleozoic contact of the east limb. There is thus, apparently, a transverse fault disrupting the west limb of this anticlinal ridge. The beds north of this transverse fault appear to belong to the Misty range, whereas the eastern side and southern end of the structure seem to have been brought to the surface by drag. The trans-

verse fault postulated above may join the Misty Range thrust.

The area north of Elbow river is largely covered with drift. Consequently, the structural details are not known. The Highwood valley syncline probably extends into this part of the area, as upper Fernie sandstones were found just north of the Elbow-Little Elbow divide. Kootenay beds lie on the west side, next the Misty Range fault, to the head of the Little Elbow drainage. North of this point, drag along the Misty Range fault has brought up east-dipping Spray River and uppermost Paleozoic beds. Apparently a smaller fault cuts off these Paleozoics to the east, as close to the north end of the basin Paleozoic rocks above the Misty Range fault are thrust over Paleozoic beds below. These in turn are faulted on Spray River strata. A band of Fernie beds outcrops in the centre, showing a general synclinal pattern.

The Mesozoic basin is pinched out on top of a ridge overlooking the main stream of Little Elbow river. In addition to the fault east of the Misty Range thrust, another smaller fault was observed on this ridge, bringing uppermost Paleozoics up on Spray River beds. The last Spray River beds are lost, here, as they dip into the fault planes of these two faults.

Chapter VI. COAL

PREVIOUS HISTORY

Coal was first reported from the Highwood-Elbow area by G. M. Dawson, who in his reconnaissance of the area in 1884 found a few small seams and many pebbles of coal in the streams (Dawson, 1886, p. 100). The first attempts to exploit the coal deposits of the area, by the P. Burns Coal Mining Company, commenced early in the present century (Cairns, 1915, p. 7). These operations, consisting of trenching and tunneling, were carried on until about 1922. One tunnel, 2,250 feet in length (Marshall, 1922, p. 93), was driven across part of the coal measures. A right of way for a railway was surveyed and cleared from Calgary up Sheep river to the Burns property, but the railway was never completed. During the last war Harry A. Ford, of Calgary, obtained coal mining leases on a block of land south of the Burns property and opened a number of prospect tunnels. At about the same time a limited amount of work was done on Pocaterra creek. From about 1922 to 1944, activity on the coal properties in the area was greatly restricted.

In 1943-44 the Dominion-wide coal shortage once more directed attention towards the coal resources of this area. Two companies were organized in eastern Canada. Allied Industrials Limited acquired mining rights from the Burns Foundaion, representing the P. Burns Coal Mining Company, on the Burns property.

Highwood Coal Mines Limited (reorganized late in 1945 as "Highwood-Ford Collieries Limited") secured an option on the Ford property.

Certain claims made by interested parties regarding the coal on these two properties made it necessary that geological work be carried out in the area.

GENERAL RELATIONSHIPS OF THE COAL

That part of the area underlain by coal-bearing strata lies within the Highwood coal area (Allan, 1940). All the coal of economic importance in the Highwood-Elbow area occurs in the Kootenay formation, although very thin seams are present in the lower part of the Blairmore formation. In the eastern part of the area, where the coal claims are located, all the coal appears to lie in the lower 500 feet of the Kootenay, but on Bishop creek a thin seam was found 75 feet below the top.

The seams have been involved in the faulting and folding, and frequently appear to have suffered more severe deformation than the sandstones and shales above and below.

COAL LANDS

The Burns and Ford coal properties are shown in Figure 4. The Burns property consists of about 13,600 acres, of which approximately 12,000 acres are patented coal lands, 320 acres are patented mineral lands and 1,280 acres are coal mining leases. The property extends from Rae creek on the north to Picklejar creek on the south.

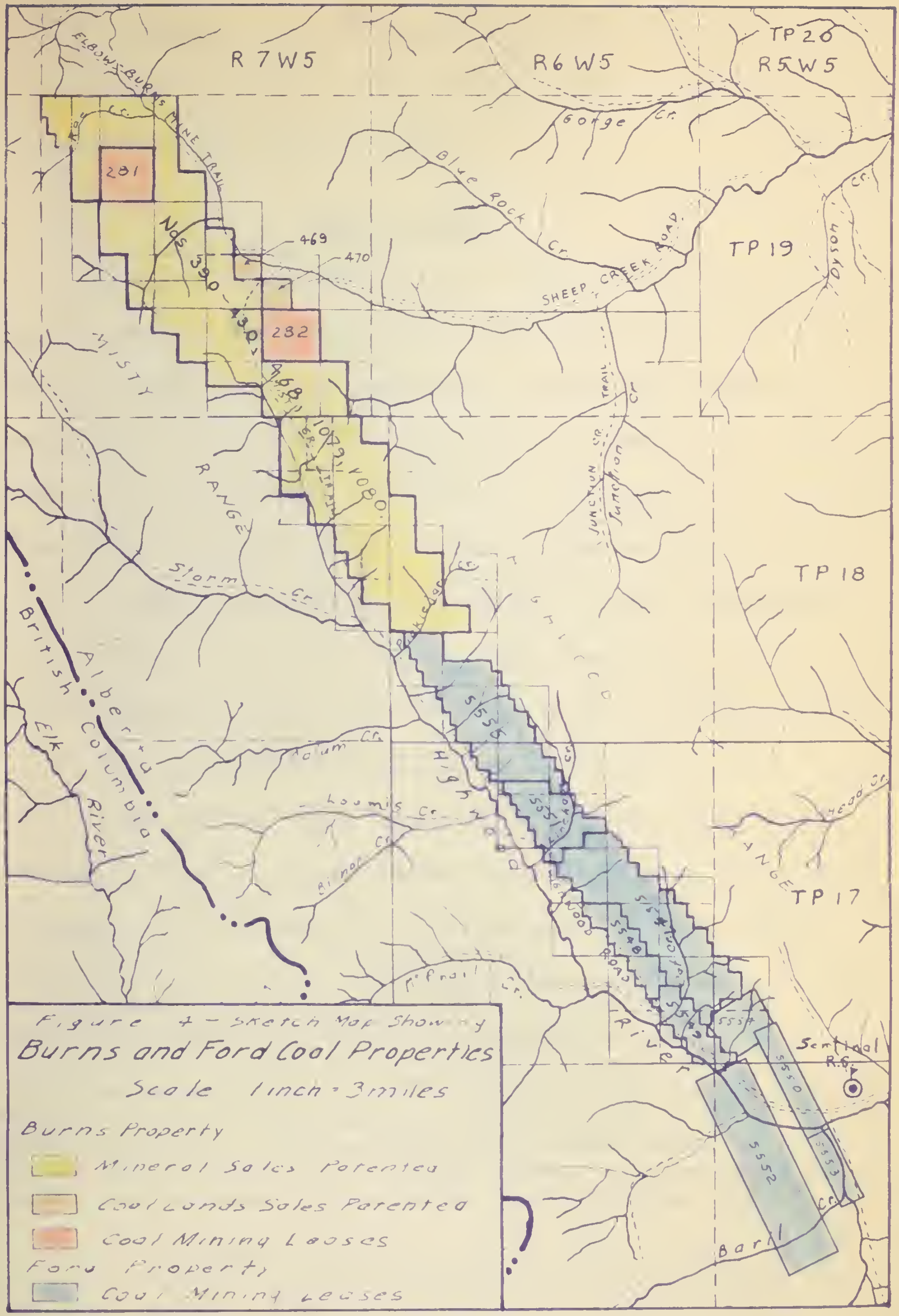


Figure 4 - Sketch Map Showing
Burns and Ford Coal Properties
Scale 1 inch = 3 miles

The Ford property consists of about 11,500 acres of coal mining leases, extending from Picklejar creek to almost three miles south of the Highwood river.

FORD PROPERTY

Highwood Coal Mines Limited obtained an option on this property in 1944 and in the winter of that year and the first two months of 1945, commenced preliminary prospecting of the coal-bearing beds adjacent to the north side of Highwood river and Cat creek. This prospecting was limited to the opening of eleven cuts by bulldozer and shovel on the outcrop of the Kootenay formation.

Three separate bands of Kootenay strata, separated by thrust faults, cross the property. These bands are referred to by the company as Zones A (on the east), B and C (on the west).

PREVIOUS GEOLOGICAL INVESTIGATIONS

In 1919 and 1920, Rose (1921, p. 18) and Allan (1921) examined the coal prospects opened along Cat creek. As the Ford prospects are badly caved, no information on the coal could be obtained by the writer. The following description by J. A. Allan (1921, pp. 43-44-45) shows the character of the coal:

"On Cat creek fourteen seams of coal are exposed and have been prospected in a distance of less than a mile across the strike of the formations. The numbering of the seams have been given in the order in which they have been opened. Beginning at the most easterly prospect the seams may be described as follows:

"No. 000. About four feet of badly crushed coal containing considerable bone, but with many lensy fragments of solid coal with high lustre. The limestone outcrops a few yards east of this prospect.

"No. 00. About eight feet of solid coal and four feet of badly crushed coal.

"No. 0. Seven feet six inches of good-looking coal.

"No. 1. Five feet glossy compact coal and about four feet badly crushed coal.

"No. 2. Twelve feet glossy and blocky coal, fourteen inches of bone, three feet six inches fair coal.

"This seam, which is eight feet from No. 1, dips at 53 degrees west and strikes north 39 degrees west.

"Very little work has been done on numbers 3 and 4, so that the exact width of these could not be determined, but Rose gives a thickness of four and five feet respectively.

"No. 5. Thirty-three feet made up as follows: 11 feet coal, 4 feet shale and coaly shale, 18 feet coal. This is one of the best seams on the property and contains much coal of good marketable quality. The strike of the seam is north 39 degrees west, and the dip 85 degrees southwest.

"No. 6 seam. Ten feet wide has been opened up about fifty feet below No. 5. This seam appears to represent the upper part of No. 5, whereas the lower part of No. 5 at this level appears to have pinched out considerably.

"No. 7. Twelve feet of very good coal has been opened up seventy feet below the level of No. 6. The strike here is north 42 degrees west and the dip 88 degrees west to 88 degrees east.

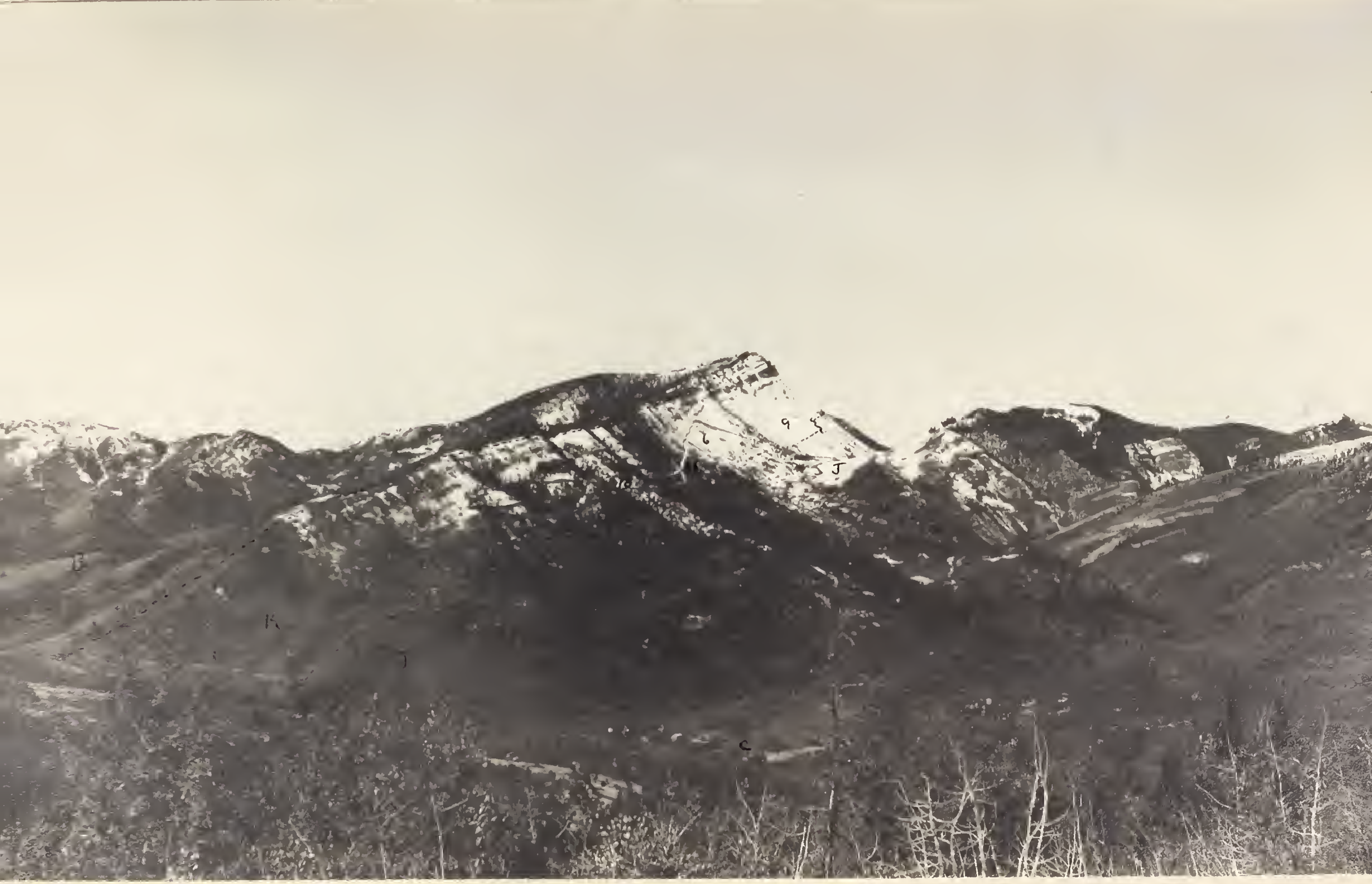
"No. 8. A five-foot seam of badly crushed coal opened up five feet below No. 7. No blocks could be obtained from this seam but the prospect does not extend beyond the weathered portion of the coal. The strike of this seam is north 62 degrees west and the dip 65 degrees northeast. There is a fault between 7 and 8.

"No. 9 has been opened up half way down the canyon of Cat creek. The prospect exposes four feet six inches of fine textured but clean coal. The strike is north 38 degrees west, and the dip about 80 degrees west.

"Between the camp and the mouth of the canyon there are two seams. The upper one, No. 10, is about seven feet wide, and the coal is mined for camp use in small but angular blocks.

"No. 11 is within a few feet of No. 10, but on account of the crushed character of the seam only twelve feet can be readily measured."

Plate XI. Zone A, from south side of Highwood river, showing bulldozed roads, open cuts (numbered), and Highwood Coal Mines, Ltd., camp (C). F, Fernie; K, Kootenay; B, Blairmore.


9
6
J
10
B
K
C

The statement by Rose (1921, p. 18), although less detailed, is essentially the same. Rose states, "The formation is repeated by faulting between No. 7 and No. 8, between No. 12 and No. 13, and probably between No. 11 and No. 12." Rose and Allan used different numbers for the seams. By Allan's terminology, the faults would occur between seams 4 and 5 and between 9 and 10. The probable fault would occur between 8 and 9.

ZONE A

Location

Zone A, the easternmost band of Kootenay in the Ford property, crosses the Highwood river about one-half mile west of the Sentinel Ranger Station. South of the Highwood, it forms a ridge which extends at least as far as Cataract creek. Zone A becomes involved in the First Fault about two miles north of Highwood river and swings to the west, but resumes a normal strike in section 12, township 17, range 6, west of the 5th meridian. Zone A crosses Cat creek and pinches out against the Second Fault in the valley of Lineham creek.

Structure

The southern part of Zone A strikes about north 35 degrees west and dips towards the southwest. South of the Highwood, dips average about 60 degrees to the southwest. On the north side, dips are frequently as low as 25 degrees to the southwest. These low dips may be sometimes due to creep. The First Fault cuts Zone A, although the displacement is probably less than 200 feet. However,

on the west side of the First Fault the strike of the Kootenay formation swings to about north 70 degrees west. In section 12, township 17, range 6, west of the 5th meridian, the continuation of Zone A meets the Second Fault and returns to a more normal strike of north 25 degrees west. Northwards, the Kootenay formation is gradually cut out by the Second Fault and the last of the coal-bearing beds pinch out in Lineham creek valley. The northern part of Zone A shows minor folding. Drag has occurred along the First Fault and the beds are badly twisted between the First and Second Faults. A small transverse fault cuts the base of the formation almost two miles north of Highwood river. A small fault is suspected to cause repetition of about 100 feet of beds just north of the Highwood river.

Coal Exposures

A number of prospect cuts have been opened on Zone A, exposing considerable coal. In addition, a few natural exposures occur.

Cut 1. (See Plate XVI for location of cuts.) This cut lies above the road on the north bank of Highwood river. It is about 800 feet in length. The cut is mostly in superficial deposits, but has been deepened to bedrock in places, to expose the coal seams. The following section is exposed in Cut 1 and along the adjacent road:

Feet	Inches		
		Top of Kootenay formation.	
335	0	Sandstones and shales	
2	0	Coal, shaly,and carbonaceous shale	
84	0	Sandstone and shale	
5	6	Coal, badly crushed and mixed with carbonaceous shale	
161	0	Sandstone and shale	
7	6	Coal (concealed by slumping; information from company officials), Egbert seam[*]	
156	0	Sandstone and shale	
7	2	Coal, with irregular lenses of shale, Connors seam (Sample #4)[**]	
104	0	Sandstone and shale	
12	4	Coal, thin shale partings, Douglas seam (Sample #3)	
153	0	Sandstone and shale	
3	11	Coal, fairly hard (Sample #2)	Holt seam
3	7	Shale, carbonaceous to silty	
1	5	Coal, crushed	
0	1	Shale	
3	0	Coal, crushed	
0	1	Shale	
3	2	Coal, crushed (Sample #1)	
0	6	Shale	
10	6	Coal, crushed, becoming shaly towards base	
40	0 ±	Sandstone and shale	
		Base of Kootenay formation	

56 feet 4 inches of coal in total section of 1,092 feet.

The coal in this cut is all very friable and badly crushed. The faces of the seams are coated with white salts, which may be due to decomposition of iron sulphide in the soil or may be derived by leaching from the overlying unconsolidated deposits. At no point is coal exposed more than twelve feet below the surface of bedrock. As will be shown in the discussion of the correlation of the seams of Zone A, the Egbert may be a repetition of the Connors, due to faulting.

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[*] The names of the seams are those applied by Highwood Coal Mines Ltd.

[**] These sample numbers refer to samples taken for analysis. See Table II.

Cut 11. This cut, in about lsd. 16, section 32, township 16, range 5, west of the 5th meridian, is shallow and has not exposed much coal. The following section was measured:

Feet	Inches	
3	0	Shale
1	6	Coal
2	8	Shale, carbonaceous
1	7	Coal
0	6	Shale, carbonaceous
3	6	Coal and shale
		Shale

Cut 10. This cut is in lsd. 1, section 5, township 17, west of the 5th meridian. One seam is exposed but slumping has obscured the details of the coal. The seam dips about 40 degrees to the west. The coal is powdery and weathered. A thickness of twenty-four feet of coal was measured but the actual thickness may be less, if creep has caused the rather low dip.

Cut 6. This cut is in lsd. 7, section 5, township 17, range 5, west of the 5th meridian. The following section is exposed:

Feet	Inches	
		Sandstone roof
30	0	Contorted powdery coal
23	0	Shale and shaly sandstone
32	0	Coal, highly contorted and crushed, with shale partings (Sample #5). (See Plate XIIIB).
15	0	Shaly sandstone
1	0	Coal, shaly
1	5	Shale
2	0	Coal, shaly, and carbonaceous shale
12	0	Shale, sandy
16	0	Coal and shale

This cut is about ten feet deep at a maximum and has not penetrated below the highly weathered portion of the coal. All

Plate XII. A. Holt seam, Cut 1, Zone A, Highwood Coal Mines, Ltd. (Photograph courtesy Dr. J. A. Allan).

B. Glover seam, Cut 4, Zone B, Highwood Coal Mines, Ltd. Headwall on right. (Photograph courtesy Dr. J. A. Allan).

A

B

the thicker seams show considerable internal folding. The strike has swung almost east-west and the sandstones above the coal show a dip of 42 degrees to the south. A small local disturbance has probably caused the contortions.

Cut 9. Cut 9 is in lsd. 12 of section 5, township 17, range 5. One nine-foot seam of badly crushed coal is exposed and a few thin seams occur along the road below the cut. The beds dip 37 degrees in a southwesterly direction.

Cut 5. This cut is on a tributary of Cat creek, in the northeast quarter of section 12, township 17, range 6, west of the 5th meridian. The cut is about 220 feet long and includes about 155 feet of strata. The east end of the cut coincides with the base of the Kootenay formation. Only one seam, at the west end of the cut, was partially exposed at the time of the writer's visit. About four feet of coal are visible. Bloom in the bottom of the cut suggests that three other seams may be present below this seam, but their thicknesses are unknown. Indeed, they may represent blocks of coal lodged in the unconsolidated materials above bedrock.

Other Exposures. Coal is poorly exposed through the rest of Zone A. Four feet of weathered coal are exposed on the bulldozed road, 1,700 feet southeast of Cut 11. Between Cuts 10 and 11 coal is encountered and for a few feet the road follows a seam, but neither top nor bottom are exposed. This material is mostly bloom.

On the road north of Cut 6, a few feet above the base of the Kootenay formation, the following section is exposed:

Feet	Inches	
3	0	Coal
3	0	Shale
0	6	Coal
2	6	Shale
2	0	Coal
3	6	Shale
5	0	Coal
2	2	Shale
2	0	Coal
30	0	Shale and sandstone, to base of Kootenay formation.

The coal is weathered and dirty.

On the small creek flowing south through section 6, township 17, range 5, west of the 5th meridian, at least fifteen feet of coal, associated with carbonaceous shale, outcrop.

On Cat creek Zone A is largely concealed. On the divide between Cat and Lineham creeks, an old trench has exposed about eight feet of coal.

Between Cat creek and the Highwood river, coal showings are frequent in the burrows of small animals.

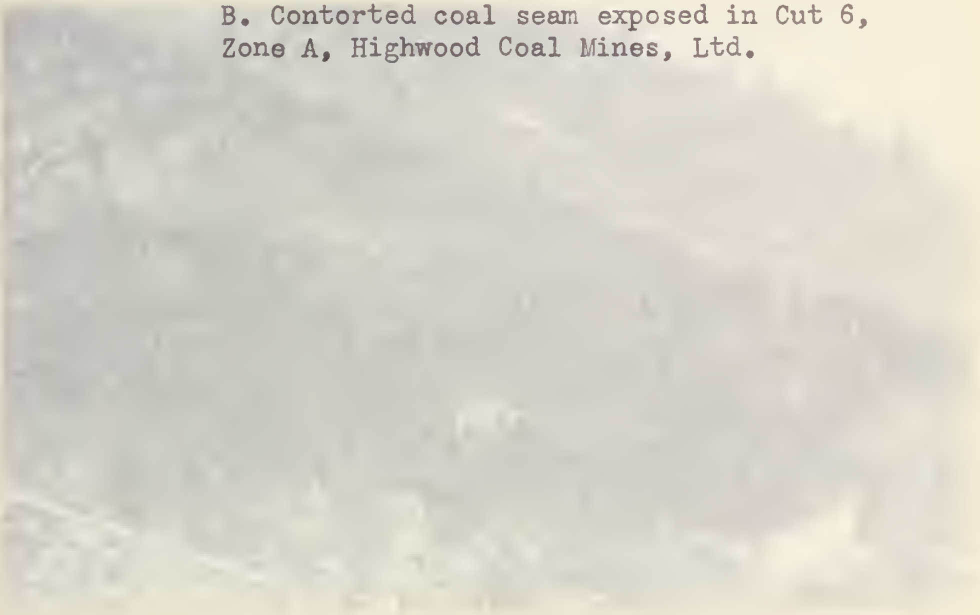
Correlation of Seams

Plate III shows the occurrence of coal seams in the Kootenay formation of Zone A near the Highwood river. The stratigraphic position is based upon a plane table survey. As far as possible the coal seams have been related to the base of the formation rather than to the upper contact, which has suffered erosion.

The only coal which may be correlated with the Holt seam of Cut 1 seems to be the series of thin seams occurring near Cut 6.

Plate XIII. A. Pile of coal brought to surface by burrowing mammal. Hammer handle one foot long. On Highwood-Sheep divide, close to trace of Third Fault. (Photograph courtesy Dr. J. A. Allan).

B. Contorted coal seam exposed in Cut 6, Zone A, Highwood Coal Mines, Ltd.



A

B

This horizon is not well exposed elsewhere.

The Douglas seam occupies approximately the same horizon as the coal in Cuts 9 and 10. The slight difference in position would be readily accounted for by small changes in dip in concealed intervals between the coal and the base of the formation. The variation in thickness of these seams is not great enough to make this correlation unreasonable.

The coal in Cuts 6 and 11, and on the bulldozed road south of Cut 11, will probably correlate. The seams in Cut 6 have been thickened by folding. However, the thickness is so much greater than in the other exposures that the writer feels that some of the coal may be concealed in these. In Cut 1, the Connors seam may correlate with the lower part of the coal in Cut 6, in which case more coal may occur above the Connors seam. That interval is not well exposed.

The Egbert seam in Cut 1 does not seem to correlate with any coal exposed farther north. According to the mine officials, this seam is seven feet six inches in thickness, which is very similar to the thickness of the Connors. The section at Cut 1 shows a thickness of 1,092 feet of beds in the Kootenay formation. It was shown in Chapter IV that the average thickness of the Kootenay is 750 to 850 feet in this part of the area and that approximately 100 feet of beds, present near Cut 1, have been removed from the top of the formation farther north. This leaves 150 to 200 feet of beds unaccounted for. The writer suggests that faulting has caused

a repeat of the Connors seam in Cut 1 and that the Egbert seam is the same as the Connors seam.

Insufficient data are available to correlate most of the other exposures with the seams in the south end of Zone A. At Cut 5, however, there is an indication of coal about forty feet above the base of the Kootenay, which is the approximate horizon of the Holt seam. The seam in Cut 5, 155 feet above the base, may correlate with the Douglas seam, although it is a little low stratigraphically.

Seams 000 to 4, inclusive, as described by J. A. Allan on Cat creek, lie to the west of the Second Fault and to the east of the Third Fault, and therefore belong to Zone A. Seam 000, which appears to be the most easterly, probably correlates with the Holt seam. The other seams cannot be correlated. Some of the old prospects in Zone A are on the same seam, only at different places along the strike of the beds, and hence some of the seams mentioned by J. A. Allan may represent the same seam.

ZONE B

Location

Zone B Kootenay strata are brought to the surface by the Second Fault a thousand feet north of Baril creek. The basal beds are first exposed southeast of Cat creek. Zone B extends north through the Ford property and into the Burns property,in continuous outcrop.

Structure

Zone B is brought to the surface by the Second Fault and for most of its length, the upper beds are cut off by the Third Fault. Transverse faulting has probably taken place in Zone B south of Cat creek. A fold occurs in the upper beds between Highwood river and Cat creek, and at least two sharp anticlines occur in the canyon of Cat creek. The beds in the long ridge west of Cat creek are somewhat folded, and on the west side drag along the Third Fault has caused some folding. North of Lineham creek, only the lower part of the formation is present. The eastern side of Zone B shows fairly low dips, while the western side, closer to the fault, shows dips of 60 degrees to 80 degrees to the west.

Coal Exposures

Zone B has not been prospected by Highwood Coal Mines Limited to as great an extent as has Zone A. Four cuts have been made on a hill in section 31, township 16, range 5, west of the 5th meridian, while one cut has been opened near Cat creek.

Cut 2. This cut lies near the base of the hill mentioned above, on the south side, and is a slight widening of a bulldozed road. The following section is exposed:

Feet	Inches	
		Shale roof
1	7	Powdery coal
0	$\frac{1}{2}$	Shale
2	2	Coal, hard, glossy, brittle (Sample #6)
1	0	Shale, highly carbonaceous

This coal occurs about 800 feet below the top of the Kootenay formation.

Cut 4. A large but contorted seam, called the Glover seam by the mine officials, is exposed in Cuts 4, 4a and 7, which are in alignment up the side of the hill. In Cut 4, the seam is somewhat folded. The footwall strikes between north 10 degrees west and north 20 degrees west, and dips west at about 90 degrees with minor undulations. The hanging wall of the seam strikes north 30 degrees west, but dips to the west at 45 degrees to 50 degrees (see Plate XII B). This results in a wedge-like seam. The greatest horizontal width of the Glover seam in Cut 4, normal to the strike, is forty-eight feet. The coal is highly crushed and slickensided. Small patches of iridescent coal are present. Lenses of shale, apparently pinched out during folding, occur in the seam. Sample #7 was collected 6 feet above the base of the seam. The Glover seam lies about 1,100 feet below the top of the Kootenay formation.

Cut 4a. The Glover seam here strikes north 35 degrees west and dips 65 degrees to the west. The coal is closely folded and badly crushed. Shale partings show minor faulting. The following section was measured:

Feet	Inches	
		Shale roof
4	5	Coal
0	1	Shale
2	0	Coal
0	2	Shale
0	4	Coal
4	9	Shale
15	10	Coal and shale, highly contorted. Sample #8, four feet below top.
		Shale floor.

Cut 7. This cut, also on the Glover seam, at the top of the hill, exposes very little bedrock. Less than ten feet of

coal seems to be present.

Cut 3. This cut lies on the south bank of Cat creek in section 12, township 17, range 6, west of the 5th meridian. The bottom of the cut is in badly weathered rock and consequently only weathered coal is exposed. The true character of the coal is not known. The following section was measured:

Feet	Inches	
		Shale and sandstone roof
4	6	Coal
1	0	Shale
0	8	Coal
0	2	Shale
0	1	Coal
1	6	Shale
0	10	Coal
1	0	Shale
0	8	Coal
		Shale floor

This section is probably not representative of the coal at depth. The coal lies about 560 feet above the base of the Kootenay formation. Due to folding, its position with respect to the top of the Kootenay formation is not known, but is probably lower than the Glover seam.

Other Exposures. A ten-foot seam of coal is exposed about one-third of a mile above the lower end of Cat creek canyon. The seam is crushed, but has very few shale partings. The bed is dipping 90 degrees to the west. This seam lies about 1,200 feet below the top of the Kootenay and Sample #9 was taken from this seam. Two hundred feet upstream, the zone exposed in Cut 3 crosses Cat creek, but is poorly exposed. Showings of coal are abundant on the ridges to the north of Cat creek, which are

underlain by Kootenay strata of Zone B, especially in burrows. Bloom on the bulldozed road north of Cut 3 suggests that coal is present within a few feet of the base of the Kootenay.

Seams 5 to 9 inclusive, by Allan's terminology, occur in Zone B.

Correlation of Seams

Largely because of the folding which the Kootenay strata of Zone B have undergone, the exact stratigraphic position of the coal seams is not known and correlation is difficult. The ten-foot seam on Cat creek may correspond to the Glover seam, as it apparently lies at about the same distance below the top of the formation. This correlation is tentative, as minor structures would influence the apparent stratigraphic position of both these seams.

Correlation of the seams of Zone B with those of Zone A is probably impossible. Zone B apparently is much thicker than Zone A, as the Glover apparently lies 1,100 feet below the top, while the maximum thickness of Zone A is only about the same amount. However, the bloom seen on the road north of Cut 3 apparently occupies a similar stratigraphic position to the Holt. The coal in Cut 3, lying about 560 feet above the base, may correspond to one of the thin seams above the Egbert seam. The other seams cannot be correlated.

The Glover Seam

The Glover seam shows a progressive thickening from less than ten feet in Cut 7, to 27 feet 7 inches in Cut 4a, and to 48 feet in Cut 4. The Second Fault lies about two hundred feet east of these three cuts. To the west is a small syncline and anticline. Internal folding in the seam has taken place. Part of the movement along the Second Fault probably took place within the Glover seam and the great increase in thickness represents a "swell" due to this movement. It is possible, too, that some of the thickening is due to closer proximity of the lower exposures to the synclinal axis. If this explanation is correct, great variations in thickness of the coal would be expected both up and down dip, and along strike. The thickness of almost fifty feet shown in Cut 4 must be regarded as purely local. At depth, it is possible that movement along the seam passes into a fault, which will cut off the seam altogether.

ZONE C

Location

The Zone C band of Kootenay is the westernmost of the three bands crossing the Ford property. It is brought to the surface by the Third Fault on Baril creek, and is also present north of Highwood river, but may not be continuous between the two points. It continues northwestwards and crosses Cat creek at the lower end of the canyon. It forms the crest and much of the western slope of the ridge that lies east of Highwood river.

Zone C is continuous into the Burns property.

Structure

The lower part of the Kootenay formation is cut off by the Third Fault, south of Lineham creek. North of Lineham creek, the entire section is present. Drag folding is conspicuous along the Third Fault, south of Lineham creek. The dip of the beds is usually 75 to 90 degrees to the west, except for the zone north of Lineham creek where the beds are overturned. Minor folds are present but are not conspicuous. Oblique faults were not recognized. No thrust faults within the zone were found. The structure is consequently rather simple.

Coal Occurrences

No development work has been done on Zone C by Highwood Coal Mines Limited. Seams 10 and 11, of Allan, are in Zone C.

Thin beds of coal occur near the fault on Baril creek, but are very highly distorted.

On the ridge south of Lineham creek, coal showings are quite abundant, in piles of dirt brought to the surface by burrowing animals. About four hundred feet above the base of the Kootenay formation, one burrow showed blocks of coal up to three inches long, two inches wide and one-half inch thick. This is clean-looking coal and does not show the crushing characteristic of the other coals seen on the Ford property. Showings in burrows are also common north of Lineham creek but this coal is all crushed.

Correlation

Due to the few exposures, no correlation can be made with certainty. Some showings indicate that coal is present at the horizon of the Holt seam. The showings are restricted to the lower part of the formation. The upper five hundred feet of beds appear to be barren.

BURNS PROPERTY

The Burns property includes the northward continuation of Zones B and C, and much of the Kootenay brought to the surface east of Misty range. While a great deal of work has been done on this property in the past, the tunnels have caved in or been blocked. Allied Industrials Limited opened one cut, from which a small tonnage of coal is said to have been extracted for testing purposes.

Structure

The geological map (Plate I) shows that the two western bands of Kootenay strata which cross the Ford property, continue north of Picklejar creek into the Burns property.

The continuation of Zone B comprises only the lower beds of the Kootenay formation, the upper having been cut out by the Third Fault. The dip of the beds varies, usually being lower in the eastern part of the band and higher on the west. The prevailing dip is towards the west, but drag folds are common close to the fault. At the head of Cliff creek, the base of the Kootenay formation is displaced slightly by a very low angle thrust, which apparently is represented a little farther north by closely folded

shales and thin sandstones in the lower beds of the Kootenay. The northern extension of this zone passes into the bottom of Sheep River valley and exposures are few. Zone B apparently pinches out against the Third Fault near Burns creek.

A measurement of the Kootenay beds of Zone C on Picklejar creek indicated a thickness of 2,100 feet. This must be considered a maximum value, as minor structural conditions may have resulted in thickening. The Kootenay strata probably maintain a constant thickness throughout Zone C, except where some beds are lost by faulting and erosion.

Zone C extends almost completely across the property. The base lies on Fernie beds brought up along the Third Fault, except for a short interval east of the headwaters of Mist creek, where the lowermost beds are pinched out at the surface. The zone is overlain by Blairmore beds, almost to Burns creek where the Blairmore formation pinches out against the fault cutting the east limb of the Highwood valley syncline. From Burns creek north, this fault cuts out the upper strata of the Kootenay of this zone. The Kootenay strata of Zone C end abruptly near Rae creek, due to faulting and folding. The beds are not severely folded in the southern part of the property. Overturning of the upper beds is pronounced north of Picklejar creek, but this may be due to creep. Folding becomes more prominent northwards, however. Sharp anticlines of small dimensions, overturned to the east, occur through

the lower half of the formation as it passes into Sheep River valley near Burns mine. The folding becomes more intense northwest of Burns mine, then gradually becomes less intense and develops into a single anticline with an accompanying syncline, bringing Fernie beds to the surface. Due to this fold, this zone of Kootenay ends abruptly at Rae creek. However, the folding at the northern end of Zone C involves the entire Kootenay section present, and not just the lower beds.

Close folding is characteristic of the strata to the west of Zone C. Two bands of Kootenay beds occur. The eastern one rises four miles northwest of the junction of Mist and Storm creeks, as two narrow strips forming the limbs of the Highwood valley syncline. These unite between Burns and Rae creeks and extend along the synclinal axis to Elbow river. A certain amount of minor folding has occurred in this band. It is bounded on both sides by almost vertical faults. This band is faulted on Zone C in the vicinity of Burns creek.

The Kootenay strata between Zone C and Misty range represent the northern continuation of the eastern arm of the band of Kootenay which outcrops on Bishop creek. This band narrows rapidly northwards and in the northern part of township 18, range 7, it becomes apparent that a west-dipping thrust fault has truncated the east-dipping Kootenay beds so that only the upper beds outcrop at the surface. Folding is intense throughout this band. Between Burns creek and Rae creek, this band is brought

in contact with the Kootenay beds of the syncline. On the west, this band is limited by the above mentioned thrust, which brings up Fernie and lowermost Kootenay beds against the upper Kootenay beds to the east of the fault. North of Rae creek, this fault cannot be traced and the Kootenay beds both above and below the fault have been mapped together to the divide between the Elbow and Little Elbow rivers. Only the lower beds are present north of Rae creek and considerable deformation of these has occurred.

Coal Occurrences

Due to the collapse or blocking of the old prospect tunnels, much less information is now available regarding the coal seams of the Burns property, than twenty years ago. The principal work has been in Sheep River valley where at least eleven small prospects have been opened and one major tunnel about 2,250 feet in length (Marshall, 1922, p. 93) was driven across part of the coal measures.

The thickness and description of the seams are given by Allan (1921, p. 48) as follows:

"The section exposed in the tunnel is approximately as follows:

950 feet	Sandstone and shale, strike north 27 degrees west, dip 70 degrees west
35 feet	Coal, Burns seam
375 feet	Sandstone and shale
38 feet	Coal, Sharp seam
140 feet	Shale and sandstone
18 feet	Coal
133 feet	Sandstone
7 feet	Coal
60 feet	Sandy shale
$3\frac{1}{2}$ feet	Coal

The tunnel terminates just beyond this seam.

"Along Sharp creek a few hundred yards west of the tunnel six seams were examined. Others are reported to occur farther up the creek but these were not visited. The following seams were examined in prospect tunnels beginning at the mouth of the valley:

No. 1 Burns seam passes west of the outlet of the valley.
No. 2 Sharp seam, 32 feet of coal.
No. 3 Seven feet six inches. This one is 18 feet in tunnel.
No. 4 Eight feet coal
No. 5 Five feet coal
No. 6 Seven feet coal
No. 7 Corlet seam; 2 feet solid coal; 4 feet 9 inches rock; 12 feet solid coal; 14 feet rock; 13 feet soft coal; no foot wall in sight.

"In Rickert creek the following seams are exposed:

No. 1 Burns seam, 20 feet coal in the foot wall, 5 feet soft rock, 9 feet 11 inches coal in the hanging wall.
No. 2 Seam, coal 21 feet
No. 3 Seam, coal 12 feet 6 inches
No. 4 Seam, coal 7 feet
No. 5 Seam, coal 9 feet 6 inches."

The writer is of the opinion that the long tunnel started in the Fernie formation. This opinion is based on the trend of the Kootenay-Fernie contact and the lack of coal in the first 950 feet of strata penetrated by the tunnel. On Sharp creek seven prospect tunnels with coal about the entries, may still be found and probably correspond to the seven seams described above. The five easterly entries are in Zone B and probably correspond to seams 1 to 5. The other two are probably in Zone C and may correspond to seams 6 and 7. Seam 7, however, appears to be similar to the Burns seam in thickness and may correlate with it, in which case seam 6 would lie east of the Third Fault. It appears that the No. 1, Burns seam, is the lowermost seam in the section and probably lies in the same horizon as the Holt seam of the Ford property. The prospects on Rickert creek were not all

found, hence it is not known how the seams there are distributed between Zones B and C.

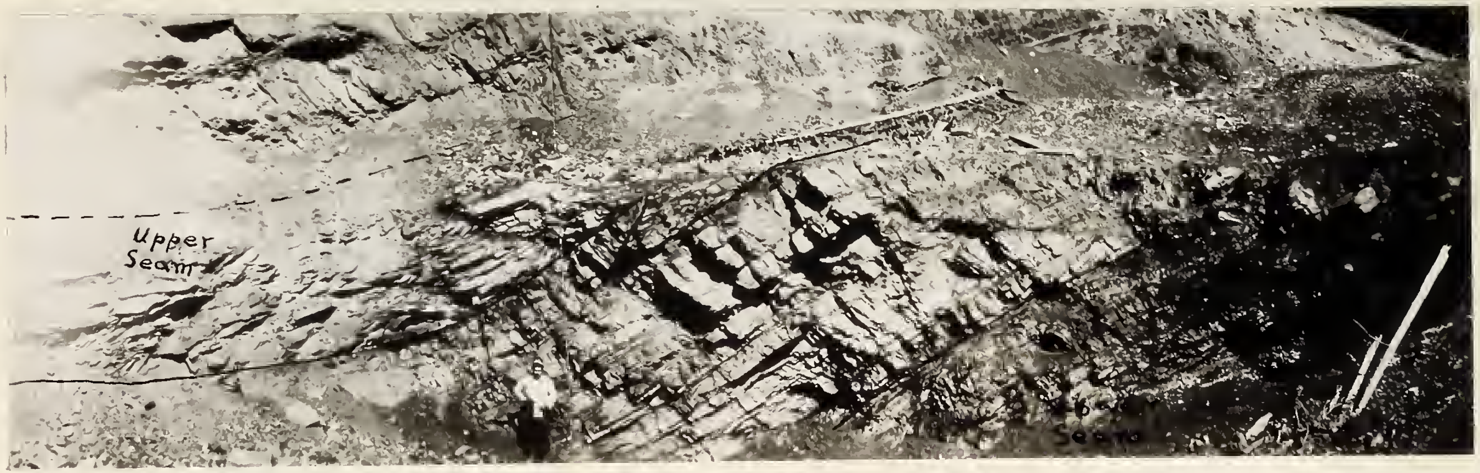
Allied Industrials Limited opened a cut about one-fourth of a mile south of the large tunnel and about 300 feet above it in elevation. The following section is exposed in this cut:

Feet	Inches	
		Roof, carbonaceous shale
9	6	Coal, hard, banded with bright and dull coal (Sample #10)
0	5	Sandstone, carbonaceous
0	7	Coal, slightly crushed
9	10	Shale, and sandy and silty shales
5	0	Coal, hard, banded with bright and dull coal (Sample #11)
2	5	Coal, somewhat crushed, becoming severely crushed toward base
0	11	Shale, carbonaceous
6	8	Coal, dirty, crushed, with small lenses of harder coal
3	10	Coal, very badly crushed and weathered
		Floor, carbonaceous shale. Floor not well exposed.

A photograph of the cut is shown on Plate XIV. About twenty feet below the floor of this seam a sandstone occurs that resembles the basal Kootenay sandstone. Immediately below this sandstone are beds similar to the Upper Fernie sandstone. It is believed that this coal occupies the same horizon as the Holt seam, close to the base of the Kootenay formation. If this is so and if the previous correlation of the Burns seam with the Holt seam is correct, then the cut is made on the Burns seam. The thickness of coal is also in agreement with this. This cut is in Zone B.

A small exposure in Zone B, about two hundred feet above the base of the formation was found four miles northwest of Picklejar creek. The following section was measured:

Plate XIV. Open cut of Allied Industrials, Ltd., Burns Property, Sheep river.


Upper Seam
Seam

Feet	Inches	
		Roof, shale
4	3	Coal, very dirty
5	0	Shale and ripple-marked sandstone
1	0	Coal
0	2	Shale
3	0	Coal, fairly hard
		Floor, shale

Several trenches in Zones B and C between Picklejar creek and Rickert's Pass, show the presence of coal but these are now caved in and no details could be ascertained. One trench, just east of Rickert's Pass, shows the presence of a five-foot seam in Zone C. Burrowing mammals frequently bring coal fragments to the surface. The finest example of this is almost on the trace of the Third Fault, as it crosses the divide between Mist creek and Sheep river (see Plate XIIIA).

Coal exposures are not common in the western part of the property. Coal occurring in the Holt seam horizon sometimes occurs but is always very badly crushed. Lensing beds of cannel occur in the upper five hundred feet of the Kootenay formation in this part of the property. These usually average two to three inches in thickness and never exceed six inches in thickness. Consequently, they are of no economic value.

BISHOP CREEK TO POCATERRA CREEK

Kootenay beds are brought to the surface by a faulted anticline on Bishop creek and can be followed northwards on both the east and west sides of Misty range. Those beds on the east side of Misty range were considered with the Burns property. The western band follows the valley of Storm creek, crosses into the

Plate XV. A. Block of coal from Cut 5, Zone A, Highwood Coal Mines, Ltd., showing cone-like pressure fractures. (x $\frac{1}{2}$)

B. Block of coal from open cut of Allied Industrials, Ltd., showing blocky character and lamination of the coal. (x $\frac{1}{2}$)

A

B

valley of Pocaterra creek and appears to be faulted out near Mount Wintour in township 20, range 8, west of the 5th meridian. The beds are closely folded and faulted. Coal showings are quite abundant in the southern part of the belt, but structural conditions are not favorable for mining. Of interest is the occurrence of a one-foot seam, 75 feet below the top of the Kootenay formation on Bishop creek.

Prospecting was carried on on Pocaterra creek some years ago. The following brief statement has been summarized from an unpublished paper by I. W. Jones (1924, pp. 52-53):

> Two 640 acre blocks were leased on Pocaterra creek, where that stream changes its direction of flow from northwest to almost west, about the centre of township 19, range 8, west of 5th meridian. G. Pocaterra held one on the north side of the stream, while F. Wright held the other on the south side. The coal measures are dipping up to 90 degrees to the west. Twelve seams, ranging in thickness from four to twenty-one feet, were exposed on the Pocaterra claim. Some of the coal is badly crushed, but some seams are very hard and blocky.

In the present survey, detailed work has not yet been done in this part of the area.

ANALYSES

Eleven samples of coal were collected by the writer from the Highwood-Elbow area and analysed in the laboratories of the Research Council of Alberta. These analyses are shown in Table II. Samples 1, 3, 4, 5, 7 and 8 were auger samples and hence are not altogether representative of the coal. Samples 6, 10 and 11 were channel samples. Samples 2 and 9 were grab samples. In addition, a large number of samples from this area have been analysed in the

TABLE II.

Analyses of Coal Samples from Highwood Coal Area, 1945.

Number	1	2	3	4	5	6	7	8	9	10	11
Analysis, capacity moisture											
Moisture %	1.3	1.4	2.2	1.9	20.1	6.7	1.9	17.4	2.7	2.5	3.1
Ash %	8.9	13.1	40.0	11.8	10.5	4.3	20.2	10.2	13.0	19.4	13.5
Volatile Matter %	15.0	15.0	13.1	14.7	20.8	20.9	16.5	21.8	18.1	11.1	10.9
Fixed Carbon %	74.8	70.5	44.7	71.6	48.6	68.1	61.4	50.6	66.2	67.0	72.5
Fuel Ratio	5.0	4.7	3.4	4.9	2.3	3.3	3.7	2.3	3.7	6.1	6.7
B.t.u./lb.	13,940	13,130	8,090	13,180	9,230	12,760	11,890	9,350	12,730	11,760	12,650
Analysis, dry, M.M.-free											
F.C. %	84.1	83.8	83.1	84.1	71.2	76.9	80.8	70.9	79.8	88.0	88.4
B.t.u./lb.	15,670	15,610	15,040	15,490	13,500	14,400	15,660	13,100	15,350	15,440	15,430
Classification	2	2	2	2	3	3	2	3	2	1	1

All samples non-agglomerating.

Classification 1 = Semi-anthracite
2 = Low volatile bituminous
3 = Doubtful - sample probably weathered coal

Description of Samples

Ford Property 1. Auger sample, 14 feet above base of Holt seam, Cut 1, Highwood Coal Mines Ltd.
2. Grab sample, top 3'11" of Holt seam, Cut 1, Highwood Coal Mines Ltd.
3. Auger sample, 2' below top of Douglas seam, Cut 1, Highwood Coal Mines Ltd.
4. Auger sample, middle of Connors seam, Cut 1, Highwood Coal Mines Ltd.
5. Auger sample, middle of 32' seam, Cut 6, Highwood Coal Mines Ltd.
6. Channel sample, 2'2" hard coal, Cut 2, Highwood Coal Mines Ltd.
7. Auger sample, 6' above base of Glover seam, Cut 4, Highwood Coal Mines Ltd.
8. Auger sample, 4' below top of Glover seam, Cut 4a, Highwood Coal Mines Ltd.
9. Grab sample, 10' seam in Cat creek canyon.

Burns Property 10. Channel sample, upper 9'6" seam, open cut, Allied Industrials Ltd.
11. Channel sample, upper 5' of lower seam, open cut, Allied Industrials Ltd.

TABLE III.

Miscellaneous Analyses of Coal Samples from Highwood Coal Area

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Moisture %	4.3	3.3	3.5	2.4	3.0	2.7	0.6	0.5	0.6	0.6	0.7	0.4	0.5	0.6	1.3	0.5	0.7	0.9
Ash %	20.0	16.3	20.8	22.7	23.7	25.2	23.6	8.7	7.6	23.9	6.8	13.9	15.4	6.0	10.4	10.3	13.0	18.8
Volatile Matter %	15.4	17.2	16.2	15.2	15.4	14.0	14.3	15.1	16.0	16.2	18.8	14.7	13.4	17.1	11.1	13.2	11.5	13.7
Fixed Carbon %	60.3	63.2	59.5	59.7	57.9	58.1	61.5	75.7	75.8	59.3	73.7	71.0	70.7	76.3	77.1	76.0	74.71	66.7
Sulphur %							0.6	0.5	0.5	0.3	0.7	0.9	0.4	0.6				
B.t.u./lb.	11,630	12,290	11,630	11,430	11,390	11,180	11,620	14,150	14,300	11,370	14,370	13,250	12,930	14,510				
Dry M.M.-free* Fixed Carbon %	82.9	80.4	80.8	82.2	82.4	83.5	83.8	84.2	83.3	81.1	80.3	83.9	85.6	79.4	88.4	86.2	87.9	85.2
Rank**	II	II	II	II	II	II	II	II	II	II	II	II	II	II	I	I	I	II

*Calculated from the equation: $$\text{Dry M.M.-free F.C.} = \frac{\text{Fixed Carbon}}{100 - (\text{Moisture} + 1.1\ \text{Ash} + 0.1\ \text{Sulphur})} \times 100$$

**According to A.S.T.M. Classification - I is semi-anthracite; II is low-volatile bituminous.

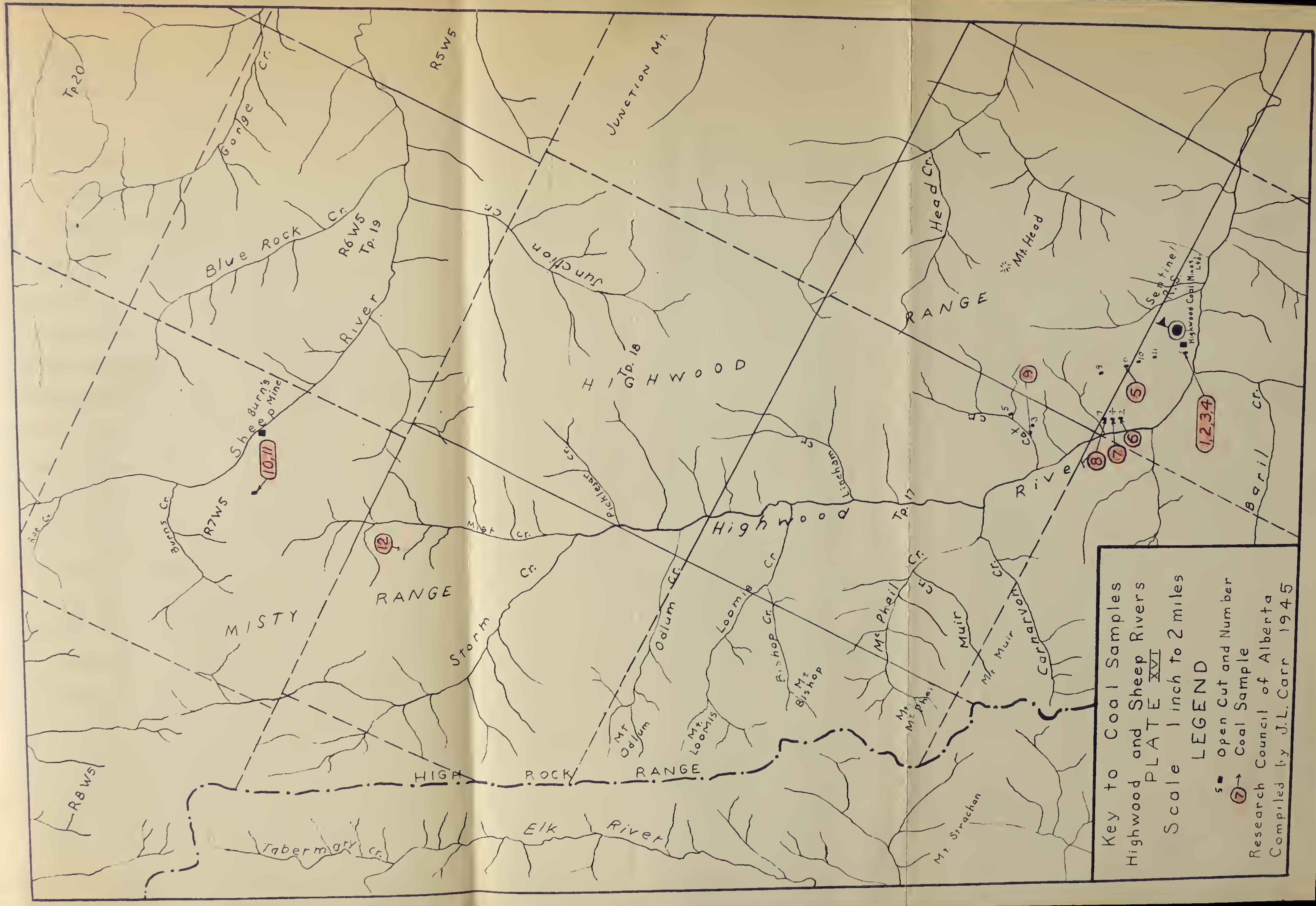
References: 1 - 6 Allan, 1921, pp. 45-46; 7 - 11 Rose, 1919, p. 199; 12 - 14 Marshall, 1921, pp. 93-94; 15 - 18 Dowling, 1914, p. 75.

1. Representative sample, Seam 6, Cat creek.
2. Average sample, Seam 10, Cat creek.
3. Average sample, Seam 5, Cat creek, upper 11 feet.
4. Average sample, Seam 5, Cat creek, upper and lower parts of seam.
5. Average sample, Seam 5, Cat creek, lower 18 feet.
6. Average sample, Seam 2, Cat creek.
7. Average sample, Seam 00, sample across seven feet.
8. Single piece sample, Seam 2, Cat creek.
9. Single piece sample, Seam 5, Cat creek.
10. Sample across seam, Seam 6, Cat creek.
11. Single piece sample, Seam 9, Cat creek.
12. Sample across 12-foot seam, 2200 feet from entry, Burns tunnel.
13. Sample from 15-foot seam, Sharp creek, Burns mine.
14. Sample from 9-foot seam, north side of Pocaterra creek.
15. Seam, 9 feet 6 inches, sec. 11, tp. 17, range 7, W. 5th, Sheep river.
16. Seam, 9 feet 6 inches, sec. 11, tp. 17, range 7, W. 5th, Sheep river.
17. Seam, 8 feet 8 inches, Sheep river, Burns location.
18. Near Tombstone mountain, Kananaskis river.

past. Several of these are quoted in Table III. Plate XVI shows the locations of the samples collected by the writer. Sample 12 shown on the plate is cannel, which is considered in Chapter VII.

These analyses show that most of the coal in the area is to be classed as low volatile bituminous, while some of the coal from the Burns property is semi-anthracite, according to the A.S.T.M. classification of coals by rank (Stansfield and Lang, Table 1,page 8, 1944). Some of the coal from Sheep river is low volatile bituminous, but in general the fixed carbon is higher in the coal from Sheep river than in the coal from the Highwood. This is to be expected as the strata in the vicinity of Burns Mine have been subjected to much closer folding and greater deformation. The Mesozoic beds on Sheep river seem to have been squeezed between the Misty range and Highwood range. If this explanation is correct, the semi-anthracite coals would not be expected to extend very far to the south, where the folding has been less intense.

The coals of the Crowsnest, Oldman and Highwood coal areas show a progressive increase in fuel ratio from south to north, indicating greater metamorphism in the same direction. Thus, in the Crowsnest area in the southern part the fuel ratio is about 1.75, while towards the northern end the fuel ratio is usually over 2.0 (Stansfield and Lang, 1944). In the Oldman area, the fuel ratio is typically 2.8. In the southern part of the Highwood area, these analyses show that the fuel ratio, for the unweathered coals, varies from 3.4 to 5.0, while on the Sheep the fuel ratio reaches 6.7.



Key to Coal Samples

Highwood and Sheep Rivers

PLATE XVI

Scale 1 inch to 2 miles

LEGEND

5■ Open Cut and Number

⑦→ Coal Sample

Research Council of Alberta

Compiled by J.L. Carr 1945

The effect of the narrowing of the basin of Mesozoic beds, with more intense deformation, is reflected in the character of the coal.

The channel samples show, almost without exception, a high percentage of ash. Picked samples show a much lower percentage. Mining methods could probably be adopted that would produce coal with a minimum of ash. High ash content seems to be more or less characteristic of the Lower Cretaceous coals of Alberta. In the Crowsnest area, ash averages from 10.2 to 14.3 per cent; in the Oldman area 11.5 per cent; in the Cascade area 7.9 to 9.8 per cent; in the Nordegg area 9.4 per cent; in the Mountain Park area 10.8 to 12.8 per cent and in the Brule area, about 13.9 per cent (Stansfield and Lang, 1944). It is possible that with careful mining practice, the ash content of the coal produced could be lowered sufficiently to compare favorably with the ash content of other low-volatile coals produced in Alberta.

Most of the coals in the area are non-coking or only feebly coking. None of the samples collected by the writer coked. Sample 11, Table III, "forms good coke" (Rose, 1921, p. 19), but as this was reported to be a single-piece sample, it is not representative of the seam as a whole. Sample 12, Table III, from Sheep river, agglomerates (Marshall, 1922, p. 93). According to the officials of the Highwood Coal Mines Limited, coal from the Glover seam is coking coal, but the analysis in Table I does not bear this out.

PHYSICAL CHARACTER OF THE COAL

In all the exposures seen by the writer on the Ford property near Highwood river, the coal was very badly crushed and so friable that it could be powdered between the fingers. The largest block seen was from the uppermost seam in Cut 5 (Plate XV A). Even this coal, however, shows numerous cone-like pressure fractures. Slickensiding is very common on the coal. Bedding is usually completely destroyed.

Allan (1921, p. 44) records the presence of blocky coal in several seams on Cat creek. These seams were examined in prospect tunnels, which extended well beyond the weathered portion of the coal. The recent cuts, however, never extend more than twelve feet below the surface of the bedrock and there is thus a strong possibility that the seams have been affected to some extent by weathering. If so, some of these seams may show blocky coal at depth.

The coal in the open cut on Sheep river shows an interesting gradation from hard, blocky coal at the top, down to soft, crushed and powdery coal at the base of the seam. Overlying the upper part of the seam is thirty to forty feet of bedrock, while the lower part of the seam is almost at the outcrop. The blocky coal has been subjected to sufficient pressure to raise it to semi-anthracite. Cone-like pressure fractures are developed in it. This bears out the idea that weathering has had a strong influence upon the friability of the coal.

Not all the seams can be expected to carry blocky coal at

depth. In many of the Kootenay coal areas of Alberta, badly crushed coal is common.

LATERAL VARIATION

The only coal-bearing horizon which was recognized throughout the area is that close to the base, which is known by the Highwood Coal Mines Limited as the Holt seam. The study of this seam shows considerable lateral variation in thickness. This variation appears to be related to deposition and not to thickening under deformation.

In Cut 1, the Holt seam shows 22 feet of coal in 26 feet 3 inches of section. Less than two miles away, near Cut 6, this same horizon shows only 12 feet 6 inches of coal in a total thickness of 23 feet 8 inches of section. Seam 000,on Cat creek, the easternmost seam in Zone A and apparently occupying the same horizon as the Holt seam, is only four feet thick. On the Burns property, the Burns seam is correlated with the Holt seam and shows 35 feet of coal in the large tunnel, while in the open cut it shows about 28 feet of coal. The lowest coal seam in Zone C on the Burns property has not been definitely determined.

In Zone A, the Holt seam shows marked variations in thickness. This is apparently caused by an increase in thickness of the shale partings towards the north, at the expense of the coal. The small seam on Cat creek further testifies to the thinning of the seam in that direction. This probably indicates that the margin of the basin of deposition of the Holt seam was not far north of Cat creek.

Equally marked are the variations in the other seams which have been exposed towards the south end of Zone A. This shows up in Plate III. The general impression gained is that the coal seams were deposited in rather small basins or else in larger basins with very irregular margins.

If these conclusions are correct, then the outlining of the basin of deposition for any one seam will be of considerable importance. Ash content should decrease from the margins of the basins towards the centres, and the coal should become thicker in the same direction. It should be realized, of course, that the basins of deposition of the different seams will not coincide, except accidentally. A few carefully-located bore holes would permit a general outline of the basins and amplification of the hypothesis.

COAL RESERVES

At attempt will be made to estimate the coal reserves of about 23 square miles of the Highwood-Elbow area. It is realized that, with the limited knowledge of the behavior of the seams at depth, these estimates are apt to be inaccurate.

The coal reserves of the Highwood coal area were estimated by Allan in 1925 at 7,000,000,000 tons (Allan, 1926, p. 43). This was revised in 1945, to 6,400,000,000 tons in an area of 90 square miles (Allan, 1945, p. D5).

The following estimate concerns only Zones A, B and C from Baril creek northwards to Rae creek. The remainder of the area is not treated, due to lack of information on the coal content,

and also because structural conditions will prevent mining operations from being carried out. Thus, there can be no comparisons between the writer's estimate and the estimates quoted above, which are for the entire Highwood coal area. This estimate concerns only the coal above an elevation of 4,500 feet, in seams four feet or more in thickness.

In Zone A, there is an average thickness of about 48 feet of coal. This underlies an area of approximately 3 square miles. If the coal averages 1,880 tons per acre-foot (the figure given by Stansfield and Lang, for Canmore low-volatile bituminous coal with 10 per cent ash: 1945, p. 106), the calculated reserve is about 190,000,000 tons. Similarly, for Zone B, with an average thickness of 60 feet of coal, over an area of about 9½ square miles, the indicated reserve is 680,000,000 tons, above an elevation of 4,500 feet. Less is known of the coal content of Zone C, but there is no indication that it is less than Zone B. So, assuming an average thickness of 60 feet of coal in Zone C, over an area of about 11 square miles, the indicated reserve is 760,000,000 tons.

These, added together, show a reserve of about 1,630,000,000 tons for about 23 square miles. This figure is probably in excess of the true value, as the coal seams are known to vary markedly in thickness. Faults not recognized on the surface may have caused local repetition of seams, resulting in too high an estimate of the average thickness of coal. Not all of this coal represents recoverable coal. A change of dip at depth would change the estimates. However, even this crude estimation shows that the area possesses large coal reserves.

Chapter VII. PETROLOGY

INTRODUCTION

The petrology of the Mesozoic sediments of southwestern Alberta has never been systematically studied. The work that has been done was principally on non-characteristic beds from widely scattered localities. Before sound ideas can be advanced as to the origin and conditions of deposition of these Mesozoic sediments, a great deal of field and laboratory work will be necessary. This will have to be carried out stratigraphically and areally, in order to be of value.

The writer regrets that in the collection of rock specimens in the field, a study of this nature was not anticipated. As is commonly the case, special types were collected much oftener than the usual type of rock. Nevertheless, specimens of all the important horizons of coarse-grained rocks were obtained. These are not altogether representative, however, as the shales and siltstones in particular were almost completely neglected.

This should be regarded as a preliminary study. The results are too few and too local to assure correct conclusions. The broad outline of sedimentation in the area, however, is probably not far wrong.

The study was based on twenty-three thin sections of specimens collected by the writer, and on several hundred immersion

mounts of crushed or disintegrated rock. Both methods have advantages and should probably be combined for every specimen. Textures can only rarely be obtained from the immersion mounts. On the other hand, rare minerals are more likely to be found in studying immersion mounts, due to the much greater volume of rock which can be studied, microscopically.

In this chapter, the descriptive petrology of each formation is considered. An attempt is then made to relate the observations with each other and to evaluate their significance. A certain amount of repetition of the stratigraphy has been unavoidable.

DESCRIPTIVE PETROLOGY

Reference should be made to Table I, the table of formations, and the sections given in Chapter IV.

SPRAY RIVER FORMATION

Basal Sandstone. This sandstone is dark grey in color and quite hard. Veinlets of calcite run through it. The bed is massive. It weathers to a light brownish grey. Dark grey shaly pellets occur in it. Towards the top, this sandstone becomes thinner bedded, with a large quantity of marcasite which stains the weathered surface green to purple.

Microscopically, the rock consists of angular quartz grains, some of which show a little regrowth, with calcite filling the interstices. Collophanite is fairly common. Zircon and apatite are the principal scarce minerals. See Slide #5 for a complete description.

Sulphur Mountain Member. The Sulphur Mountain member consists of dark grey to dark brown shales at the base, which grade upwards into dark grey, red-brown weathering siltstones and silty and sandy carbonate rocks. These beds rarely weather grey. Ripple-marking is fairly common on the bedding planes. The beds separate readily into platy slabs.

The silty carbonates consist of varying proportions of calcite and dolomite, and very fine quartz grains. The quartz grains usually lie in the upper part of the "silt" division of the Wentworth Grade Scale. They are generally angular. The surfaces are commonly dirty. Inclusions in the quartz are common. Pinkish grains of gypsum are present but not very abundant in every sample examined. Rare prismatic grains of tourmaline occur and rounded flakes of muscovite are present. Iron, which is probably responsible for both the dark grey color and the brown weathering of the rocks, is present but its form was not determined.

Whitehorse Member. This member consists of light grey to pink sandy limestones, calcareous sandstones and cherty limestones. Some beds consist of silicified Lingula coquina. Fossils are locally abundant, but poorly preserved. Much carbonaceous matter is frequently preserved with the fossils.

The silicified coquinas consist almost entirely of silica, as grains, as quartz regrown about the clastic grains and as cryptocrystalline silica or chert. Spherulitic chalcedony is rare.

Some calcite is present. Phosphate is present as the shells of Lingula and resembles the mineral colophanite. Heavy minerals are rare, the only one noted being zircon.

A fossiliferous sandy limestone from the upper beds exposed on the divide between Cliff creek and Sheep river, proved very interesting. About 25 per cent of the rock is insoluble in dilute hydrochloric acid. The average grain size is about 0.1 mm. Well-rounded quartz grains are very abundant, making up about 70 per cent of the residue. Gypsum is also extremely abundant and makes up most of the rest of the residue. It is pinkish in color and tends to show crystal outline. About 1 per cent of the residue consists of zircon, rutile, tourmaline and muscovite. There are two forms of zircon present. One form, the commoner, consists of angular grains showing crystal faces and is much smaller than 0.1 mm. in diameter. The other type consists of highly rounded grains which are approximately the size of the quartz grains. Rutile sometimes shows traces of crystal outline. The muscovite occurs in flakes with rounded edges, showing that it is allogenic or detrital. The heavy mineral suite of this rock is more abundant than that of any other rock examined, lying stratigraphically below the upper part of the Blairmore formation.

The grey and pinkish limestones at the top of this member are quite interesting, because of their close resemblance to Paleozoic rocks. Grey chert is quite abundant. The insoluble residues besides chert, consist largely of fine grained, angular to subangular quartz. Pinkish gypsum is present in small quantities.

Heavy minerals are very rare and consist of highly rounded zircon, rare muscovite and a very rare mineral identified as hypersthene. The pink sandy limestone contains some iron which is probably responsible for the color.

FERNIE FORMATION

Lower Shale. This is a dark brown to black calcareous shale, with beds of black argillaceous limestone. Most of the insoluble residue consists of dark brown clay material, which probably owes its color to organic matter. The only identifiable mineral was extremely fine-grained, very angular quartz. The top of the shale is probably ripple-marked, as the bottom surface of the overlying sandstone shows casts of ripple-marks.

Lower Sandstone. This group of beds consists of fine sandstones and associated siltstones, with a minor amount of shale. The term "siltstone" in this thesis, is used to denote those sedimentary rocks in which the grain size lies between 0.004 and 0.06 mm., which are the limits of the silt grade of Wentworth.

The lowest bed is a sandstone, fourteen feet thick, dark grey in color and fairly hard. It weathers buff-grey. This sandstone is thin-bedded and usually platy. Calcite is usually present. Worn belemnite guards occur at the base. The insoluble residue consists largely of subangular to subrounded quartz grains, averaging 0.07 mm. in diameter. Tourmaline and zircon are present in very small quantities. Pyrite occurs as cubes. Organic matter coats many of the quartz grains. The bed gives a weak test for phosphate.

A bed of sandstone with abundant small phosphate nodules and considerable pyrite overlies the sandstone. Quartz is the only detrital mineral recognized. This sandstone is much coarser than the underlying sandstone, as the quartz grains average 0.15 mm. in diameter. The pyrite occurs disseminated, in cubes, and replacing belemnite guards.

Overlying this are almost 30 feet of siltstones and shales, usually light grey in color and non-calcareous. Very fine-grained quartz and chert are the principal constituents. Orthoclase, which is fairly fresh, is present in very small quantities. Biotite, apatite and augite are very rare.

Near the base of these silty beds is a zone of phosphate nodules. These nodules are up to 2 inches in diameter and usually show an egg-like shape. A thin layer of marcasite, about 1 mm. in thickness, coats the outside. Marcasite is also present in the interior of the nodule. The groundmass is isotropic and almost opaque. These nodules give a strong reaction for phosphate.

Overlying the siltstones is a four-foot bed of calcareous sandstone, carrying Rock Creek fauna. The insoluble residue consists largely of quartz grains averaging 0.1 mm. in diameter. Foraminifera are abundant. These apparently were preserved in opaline silica, which is now partially crystallized. Altered plagioclase, augite and bleached biotite or phlogopite are present in very small amounts.

Upper Shale. Above the sandstone carrying the Rock Creek fauna is a succession of black, grey and olive shales, usually fissile. In the lower part, these carry ferruginous, argillaceous limestone concretions which vary in size from about one to six feet in diameter. The smaller ones are quite symmetrical and are shaped like an oblate spheroid. Some of these concretions carry small transparent quartz crystals in cracks. The concretions are dark grey in color, but weather to a bright orange-yellow. Cone-in-cone occurs quite frequently in these concretions. Shearing has occasionally taken place along the sides of the cones, tilting them slightly, so that one edge is upturned. This results in rows of scallops which pass across the surface of the concretion.

Upwards, the shales become lighter grey in color and sandy. Plant fragments are present but fossil pelecypods show that marine conditions were still continuing. Thin fine-grained brownish sandstone beds appear. These are frequently very finely cross-bedded. By a decrease in the amount of shale, these beds grade upwards into the upper sandstone of the Fernie Formation.

A peculiar form of calcite is quite abundant in these beds. It occurs as stellate forms, with from 4 to 20 rays radiating from a centre, in section. The form as a whole, tends towards a sphere. In some cases, a concentrically-banded centre is observable. In crushed mounts, the calcite appears to be fibrous. The general form of these aggregates closely resembles the siderite oolites which are described from the Blairmore formation, later in this chapter. There is a possibility that this calcite represents

pseudomorphs after twinned gypsum, but the concentric centres do not agree with that explanation. These forms reach 3/4 inch in diameter.

Upper sandstone. This is a massive sandstone, in beds up to 6 feet thick, but usually about 4 feet thick. It is sometimes crossbedded. It is dark grey-brown on a fresh surface and weathers a light grey-brown. It frequently fractures parallel to the face of the outcrop, in slightly curved slabs. Lenses up to 3 feet thick of a hard, yellow-brown weathering, dark grey slightly calcareous sandstone occur in it.

Microscopically, this sandstone is seen to consist of regrown quartz, argillite, chert and quartzite, and some calcite and rare zircon and vesuvianite?. Limonite is present. The rock is largely cemented by quartz. Grain size averages 0.12 mm. (See Slide #12).

The hard yellow-weathering lenses are remarkably different. They consist of extremely angular fragments of quartz, with some rock fragments, set in a dense, almost opaque groundmass, which carries some carbonate. (See Slide #22). Zircon and garnet are very rare constituents.

Brown Sand of Turner Valley. Samples of the Brown Sand of Turner Valley were obtained from the Alberta Petroleum and Natural Gas Conservation Board, for comparison with the upper sandstone of the Fernie formation. It consists of fine grains of quartz, argillite, chert and rare zircon, apatite and muscovite. The percentage of rock fragments is about the same as in the upper Fernie sandstone, and

is lower than in any Kootenay sandstone examined. The color of the two sandstones is very similar. It is probable that the upper Fernie sandstone of the Highwood-Elbow area, and the Brown Sand of Turner Valley correlate. Hume (1933, p. 52) first suggested that the Brown Sand was Jurassic in age. These results suggest that Hume was correct.

KOOTENAY FORMATION

Basal Sandstone. This sandstone is light to fairly dark grey and weathers light grey to slightly pinkish. The bed varies in thickness from 19 to 29 feet. It is highly crossbedded. The dark coloration appears to be due to black grains, since the lighter phases have very few. Slide #9 is the light phase,while Slide #10 is a darker phase. The rock is extremely hard.

The grain size averages 0.2 mm. in diameter, and is thus much coarser than the underlying Fernie sandstone. The rock is composed of quartz, and argillite, chert and quartzite fragments. The rock fragments are more abundant than in the Fernie sandstone. The quartz is regrown from an originally very well rounded shape. The rock is tightly cemented with quartz. Zircon is fairly abundant, and slightly altered orthoclase,and biotite,are also present.

Some of the interstices between quartz grains are filled with extremely small crystals. The indices of refraction are a little higher than quartz. The birefringence is low. Crystal outlines vary from a prism to an irregular hexagon. Many of the crystals show striations perpendicular to their length. Some of

the prisms are slightly bent. This material is probably closely related to some of the mica group, or the clay minerals. Indeed, it most closely resembles photographs of kaolinite (Ross and Kerr, 1931). As it occurs in several specimens, it will be referred to as "kaolinite?".

Lower Part of the Kootenay Formation. The lower part of the Kootenay formation is predominantly fine grained, and dark grey to dark brown in color. The principal lithological types encountered are coal, shale, siltstone and fine sandstone, with minor amounts of ironstone in the form of nodules. Crossbedding is quite common, and ripple-marking is not rare. Coloration is due in large part to the carbonaceous matter present. The sandstones show some black chert and argillite grains. A peculiar dark grey siltstone is characteristic. It weathers a bright orange-yellow. The weathered surface is faintly channelled, as though by corrosion, like a limestone. These rocks do not react with dilute hydrochloric acid, but carry some carbonate which is probably siderite.

Upper Part of Kootenay Formation. The upper part of the formation is marked by the presence of more sandstone and less shale, less black carbonaceous beds and an increase in the black chert and argillite grains. Lenses of pebble conglomerate occur in some of the sandstones. The section of the Kootenay formation in Chapter IV shows that in an individual sandstone bed, the grain size usually decreases from the base upwards. Crossbedding is usually present. The general color is grey-brown to brown, due to the presence of limonite. The limonite is sometimes present in tiny pockets, giving

a fresh surface of the rock a "measled" appearance. Locally, concentrations of the black rock particles result in rocks with almost no light-colored material in them (see Slide #23). The pebbles in the conglomerate lenses consist of chert, argillite and white quartzite. Small pieces of ironstone, which are of roughly the same shapes as the pebbles, occur in association with them.

The upper Kootenay strata are largely composed of quartz, chert, argillite and quartzite. Carbonaceous matter is also present. Orthoclase, only slightly decomposed, is fairly abundant. Pyrite and limonite are not uncommon. Muscovite, sericite, "kaolinite?", apatite, biotite, chlorite and zircon are rarer. The sandstones are sometimes cemented by calcite, which also occurs sparingly in most of the samples. Quartz cementation is more common.

From the upper Fernie shales to the top of the Kootenay formation, the amount of feldspar increases slightly, the amount of dark chert and argillite increases markedly, and the grain size becomes greater.

Cannel. In the upper Kootenay beds exposed west of the Highwood valley syncline, from Bishop creek northwards along the east side of Misty range, thin lenses of a cannel coal occur. These are usually two to three inches in thickness, but reach a maximum of six inches. Frequently the beds are rather shaly, but the purer beds are quite massive. The material has a hardness of about 2.5. The cannel is tough, however, and is rather hard to break. It breaks with a conchoidal fracture, leaving a checked

surface. In color, the cannel is black with a dull surface when weathered, but with a vitreous lustre on the fresh surface. The specific gravity determined with the Joly Balance is 1.2, while with the Westphal's Balance, it is 1.20. This was determined on material from the mine bed as the sample of which the analysis is given below. Streak is brown.

The cannel burns readily with a long yellow smoky flame, swelling and intumescing. A sample was analysed in the laboratories of the Research Council of Alberta and the following results were obtained:

		As Received	Capacity Moisture	Dried
Moisture	%	1.3	2.2	
Ash	%	10.7	10.6	10.8
Volatile Matter	%	59.1	58.6	59.9
Fixed Carbon	%	28.6	28.6	29.3
Sulphur	%	0.9		
B.T.U. per pound		14,020	13,890	14,200
Fuel Ratio (F.C./V.M.)		0.5		

The cannel cokes poorly.

The material is slightly soluble in xylol. This liberates a large number of extremely small yellowish, ovoid bodies, which Dr. E. H. Moss of the Department of Botany, identified as pollen grains. The cannel was also treated with nitric acid and potassium chlorate, an oxidizing mixture, in an attempt to obtain more organic remains. Only pollen grains were found. A thin section was made but this did not reveal much information concerning the nature of the coal. Most of the coal is composed of a dark reddish-brown, translucent structureless material. Pollen

grains are not abundant. Other organic forms are almost absent, but a few indeterminable fragments are present. Some of the ash occurs as minute, sharp quartz grains.

The cannel grades into a hard, white-weathering siltstone which is a high-ash cannel, by an increase in inorganic constituents. The weathered surface of some of the cannel is coated with a white material, which is similar to the white material on the surface of the high-ash cannel. This white material is chert, but also carries some clastic quartz. Rare nodules of chert are present in some of the cannel. The white material probably represents chert which was deposited with the cannel and has been left on the surface due to its greater resistance to erosion.

A slide of the high-ash cannel was obtained (slide #4). This slide is very interesting, as it shows that the cannel is composed of pollen grains, structureless organic matter and larger, carbonized plant fragments. No real spores were identified in the cannel at all.

Ashley (1918, p. 8) defines cannel coal as follows: "Cannel coal is a massive non-coking, tough, clean, block coal of fine, even, compact grain, dull lustre, commonly conchoidal cross fracture, having a typical low fuel ratio, a high percentage of hydrogen, easy ignition, long yellow flame, black to brown greasy streak, and moderate ash, pulverulent in burning." This description fits the cannel from Highwood-Elbow area very well and this cannel is therefore named correctly. The property of swelling and

intumescing is not characteristic of cannel, however. Mallett (Moore, 1940, p. 101) applied the name "Byerite" to a spore coal which swelled on heating.

BLAIRMORE FORMATION

Basal Conglomerate. This bed is 20 to 30 feet thick throughout the area. It consists of white, grey, green and black pebbles, averaging one inch in diameter, set in a hard quartzitic sandstone matrix. Joints cut through pebbles and matrix alike. The pebbles are well-rounded, but tend to be flat. The jet black pebbles are usually argillite, while the really white pebbles are quartzite. The other pebbles may be chert, argillite or quartzite. Table IV, prepared from microscopic examination of almost 100 pebbles from various parts of the area, shows the composition.

TABLE IV.
Pebble Composition of Basal Blairmore Conglomerate

Color	% of total	Chert %	Quartzite %	Argillite %
white	28	50	50	0
grey	36	75	0	25
green	12	63	12	25
black	24	62	0	38
% of total		64	15	21

The chert in the pebbles can not be distinguished microscopically from chert nodules in the upper Paleozoics of the Rocky Mountains. The matrix of the conglomerate consists largely of quartz, chert and argillite cemented by regrowth of the quartz.

Pyrite cubes are fairly common. Zircon, biotite, muscovite, tourmaline and apatite are rare.

Occasionally, lenses of coarse white crossbedded sandstone occur in the conglomerate. These have little or no dark material in them.

The conglomerate bed which occurs below the typical conglomerate in the northern part of the area, consists of black and dark grey chert and argillite pebbles. The matrix is finely crystalline silica, some of which appears to be chert.

Lower Blairmore. Above the basal conglomerate is a series of fine-grained thin-bedded grey sandstones, shales and fresh-water limestones. Coal in very thin seams is rare. One dark grey fissile shale bed about 1½ feet thick, in the upper part, carries marine fossils.

One type of sandstone is characteristic of the lower Blairmore beds. These sandstones are fine grained, light to fairly dark grey and very hard. They occur in massive beds usually less than two feet thick. When exposed on a dip slope, the upper surface of such a bed tends to weather into a series of rough hemispheres, bounded by polygonal outlines, which may be related to healed joints. The rock is composed largely of quartz. Very fine grained silica is also present and may be chert. This fine silica is authigenic. Regrowth has occurred and the chert-like silica may be quartz which has grown around a number of very fine grains of quartz. Zircon and tourmaline are not uncommon.

The freshwater limestones are also characteristic of the Lower Blairmore. These are dark bluish-grey and weather to a light grey. Frequently they are very fossiliferous and are rarely coquinal. The beds are lenticular and may occur at any horizon in the member. Sometimes these limestones occur in nodular bands. A small amount of clastic material is usually present. This consists largely of clay, but there are also quartz grains averaging 0.08 mm. in diameter, chert, zircon and tourmaline. Pyrite is present.

The shales of the lower Blairmore are usually not fissile, but weather to irregular fragments. The shales should possibly be referred to as "claystones". They are grey to dark grey in color, but frequently weather brownish. The marine shale is quite fissile.

Upper Blairmore. The upper Blairmore strata are generally fine grained, sandy shales, usually green in color, with lesser amounts of massive arkose and sandstone, volcanic tuffs near the top, and concretionary limestone. These strata are differentiated from the lower part of the Blairmore on the basis of color.

On Picklejar creek, the base of the upper part of the Blairmore formation was drawn at the base of a green sandstone, with lenses of chert and quartzite pebbles in it. The pebbles average about one inch in diameter. The matrix is fairly soft and distinctly green. Most of the rock is composed of chert and argillite fragments, with considerable quartz and some calcite. Orthoclase is abundant. Biotite, apatite and zircon are present in small quantities. The green coloration is due to a chlorite mineral, which occurs in shreds and as decomposed grains of a ferromagnesian mineral.

The green shales and sandy shales of the upper Blair-

more can be considered as a unit. The coloration is due mostly to chlorite. Quartz, feldspars and rock particles make up the bulk of the rocks. Both orthoclase and soda plagioclases are present in abundance. These vary from fresh to altered, but altered grains are the more common. The orthoclase is usually less decomposed than the plagioclase. Calcite is quite abundant. Zircon, apatite, muscovite and biotite are the usual rare minerals. Some pyroxenes are present, but these are usually altered. Tourmaline is present in some specimens. Rutile is rare. Magnetite and pyrite are sometimes present. (See slide #13).

Dark chocolate-brown weathering limestone concretions are quite abundant. These vary from ovoid to irregular, and sometimes occur as lenticular beds. All of these that were examined carry the regular clastic minerals in a calcite matrix. (See slide #17).

The harder and coarser phases of the upper Blairmore may be either sandstones or arkoses. They vary in color from greenish grey to brownish grey. Grain size is very variable. Only one of these, an arkose, was found to be of use stratigraphically. A measured section of this arkose is given in Chapter IV. Slide #11 is of this rock. Some of the sandstones have few feldspars,but carry abundant quartz, chert and argillite. These are usually light grey in color.

An important horizon consists of lensing beds of igneous pebbles in green arkosic sandstone. In the Highwood-Elbow area, the pebbles were rarely over one inch in diameter. The commonest pebbles consist of feldspar porphyry, but include grey to pink granites, greenish syenite and pink, green and white quartzite, as well as chert and argillite. One dark grey limestone pebble, with fossil fragments, was found. The porphyries are generally grey, green or pink, with a few purple pebbles.

Upwards, the clastic sediments become interbedded with tuffaceous rocks, which are correlated with the Crowsnest Volcanics. A discussion of the uppermost beds of the Blairmore formation, naturally centres about the tuffs. Consequently, all the upper beds of the upper part of the Blairmore are discussed in the next section, with the tuffs.

Tuffaceous Beds. Extending down at least two hundred feet below the top of the Blairmore, and probably occurring throughout the upper five hundred feet, are beds of volcanic tuff. Interbedded with these are normal upper Blairmore sediments.

Most of the tuffs are in beds up to three feet thick. The rock is dense and hard and is usually dark green to dark purple. Bedding is absent. These rocks are very fine grained. Some of these tuffs have cavities filled with calcite, quartz and zeolites. Several thin sections were obtained, which are described in detail. (Slides # 7,14,18,20,21) These tuffs consist of a dense groundmass of devitrified glass, with larger grains of orthoclase and plagioclase

(the former more abundant), rare quartz, zircon, biotite, chlorite, calcite, zeolites, pyroxenes, etc. Some of the larger grains represent ordinary clastic sediments deposited with the glass.

Another type of tuff is much coarser, much softer and lighter in color. This is usually green. Large chards are abundant. These reach almost 0.1 mm. in diameter. Both green and colorless glass is present. Other minerals include quartz, tourmaline, zircon, apatite, rutile, orthoclase, biotite and secondary calcite.

Tuffaceous calcareous nodules are also present. These nodules, in the hand specimen, cannot be told from the brown-weathering nodulesof the non-tuffaceous beds. Some of this limestone carries marine fossils. Other minerals include quartz, orthoclase, plagioclase, garnet, zircon, biotite, muscovite, rutile, tourmaline, chlorite and augite.

Shales interbedded with the tuffs also carry considerable glass and may be largely tuffaceous.

Maroon shales occur near the top. These do not occur in very thick beds. Some of these maroon shales are mottled with green. In addition, many of the tuffaceous beds weather red, but this is purely a surface feature. Small bean-shaped nodules of limonite are quite abundant. Oolitic siderite was found at one locality, in a thin nodular bed (see Slide #19).

At or near the top of the formation, a thin conglomerate is sometimes present. This consists of chert and quartzite pebbles, white to dark grey, in grey sandy matrix. The rock is hard, but is not so well consolidated as the basal Blairmore conglomerate. Grey sandstones, with little or no feldspar, but made up of quartz and chert and argillite grains are also present near the top. These sandstones are usually overlain by tuffs.

LOWER ALBERTA FORMATION

Only the lower part of the formation is present in the area mapped. On the east side of the Highwood range, Hage (1943, p. 11) gives a thickness of 1,900 feet for these beds, while only the lowermost 600 feet of Lower Alberta strata were found in the Highwood-Elbow area. This discussion deals only with this lower part of the formation.

Coarse Sandstones. Lenses of coarse sandstone occur near the base of the formation. These are light grey and fairly hard. Small lenses of carbonaceous matter are quite common in them. Locally white quartzite and black chert or argillite pebbles are present. These are usually about one-half inch in diameter. Rolled pebbles of coal, of the same size, are sometimes present in the more conglomeratic phases. At one locality, on Baril creek, a dark brownish-grey conglomerate, 4 to 6 inches thick, occurs at the base of the formation. The pebbles are black to dark grey chert and argillite, firmly cemented in a fine

sand matrix. Joints cut across pebbles and matric alike. At other localities, this conglomerate was not observed, but a few chert pebbles up to about one-quarter of an inch in diameter may occur in the lowermost two inches of the shales.

These coarse sandstones are usually very calcareous, thus differing from the "grit bed" of the outer foothills which is siliceous (Fox, 1942). They are composed largely of quartz, and chert. Fragments of silicified plant stems are quite abundant. Biotite and zircon are rare. Some selenite is present.

Shales. The shales are dark grey in color but are frequently stained to an orange yellow by iron oxide. They are quite fissile. Some are sandy. Selenite crystals are quite abundant in these shales and quartz and calcite crystals are also present. The shales have thin sandstone and silty limestone lenses interbedded. Apart from clay minerals, the chief minerals present in the shales and associated sandstones and limestones are quartz, chert, argillite, orthoclase, plagioclase, zircon, tourmaline, rutile and chlorite. Augite is very rare. Muscovite is locally very abundant.

Clay Shales. These beds are light colored, grey to orange brown. In most outcrops they occur as a clay, which is quite plastic and is very greasy when wet. These clays were first mistaken for bentonite, but do not show appreciable swelling in water. On Highwood river above the mouth of Bishop creek, an orange-brown phase, very rich in biotite crystals, were found con-

solidated. This rock closely resembles a tuff in the hand specimen. Calcite is the cementing agent (see Slide #3).

The rocks consist largely of a very fine clay material. The residue after washing, consists of quartz, orthoclase which sometimes shows Baveno twins, soda plagioclase, zircon, garnet, apatite, analcite, biotite, an altered mica and an unknown mineral. The feldspars are unaltered. The zircon occurs in beautiful doubly terminated prisms which show no sign of rounding. The biotite also occurs in hexagonal flakes which cannot have travelled far.

The altered mica is quite abundant. The residue from the biotite-rich orange-brown phase shows a gradation from almost opaque crystals of biotite, which give a sensibly uniaxial figure, to colorless flakes which give a biaxial figure of small 2V. As the color becomes less, 2V increases. At the same time, the basal flakes of the altered mineral show aggregate polarization effects. The flaky character is lost, so that the grains may orient themselves in an immersion mount either on the base or on the side. Those grains lying on the side show irregular cleavage lines, subparallel to the base, and undulatory extinction. Small elongate holes occur at right angles to the cleavage. In the colored grains, pleochroism similar to that of biotite but weaker, is present. Birefringence is very low, however. The index of refraction lies between 1.55 and 1.58. In some samples of the clay-shale from other localities in the

area, no biotite is present and all of the altered mica mineral is colorless. The material is biaxial and negative. Plate XXI B shows this mineral.

The grains lying on their sides show a superficial resemblance to kaolinite, pictured by Ross and Kerr (1931). It is not altogether like it however. Below, in tabular form, the properties of kaolinite and the "muscovite-like kaolin mineral" of Ross and Kerr are compared with the properties of the mineral described above.

	Altered Mica	Muscovite-like Kaolin mineral	Kaolinite
Optical character	-	-	-
2V	low	60° ± 5°	18° - 57°
Indices of refraction	1.55 - 1.58	1.557-1.573	1.561-1.566
Birefringence	low	0.014	0.005

This table shows that the optical properties of the decomposed mica are quite similar to those of kaolinite. In addition, kaolinite frequently contains small holes elongated in the direction of the c axis of the enclosing crystal.

This decomposed mica is thus quite similar to kaolinite. There is a possibility that it is related to the vermiculites, although it shows no swelling on heating. It is therefore referred to as the kaolinite-like mineral.

The unknown mineral occurs as beautiful diamond shaped colorless plates. The acute angle of the "diamond" measures seventy-four degrees and the obtuse angle is 106 degrees. The acute angle is frequently truncated, by what is probably a crystal face. Zonal growth is apparent, the zones following the outline of the crystals. The centre is usually clouded with decomposition products. The diagonals from the apices form an angle of about 80 degrees, so that the mineral is either monoclinic or triclinic. Individual crystals are sometimes united along a plane parallel to the long axis of the crystal. Reentrant angles along the margin of a crystal sometimes occur. These apparently are not related to twinning, as the grain polarizes as a whole. The size of the crystals varies from 0.08 to 0.2 mm.

The mean index of refraction lies between 1.61 and 1.64. Birefringence is low, only the thickest plates giving yellow of the lowest order. The plates give an ill-defined biaxial figure, with a large optic angle. If the interpretation of the figure is correct, the mineral is positive, biaxial. The figure is well-centred. Extinction is parallel with the long axis of the plate and inclined 10 degrees to the shorter axis.

CONCLUSIONS

The strata of Mesozoic age in the Highwood-Elbow area may be divided petrologically into two groups. The lower group is composed of the Spray River formation alone, while the upper group includes the rest of the Mesozoic beds considered in this thesis.

LOWER GROUP

The Spray River formation appears to be more closely related to the Paleozoic sedimentation than to the Mesozoic, despite the great time break below it. It represents a continuation of the transition from Chiefly chemical deposits, as in the Upper Paleozoic, to the chiefly clastic deposits of the post-Triassic beds.

The origin of the clastic components of the Spray River formation is not definitely known. The formation thins very rapidly to the east (Warren, 1945), so that the upper Paleozoic beds were probably being eroded during Spray River time, to the east of the site of deposition of these beds. Considerable sand occurs in the Rocky Mountain formation of Pennsylvanian age, and this may have provided a large part of the sand for the Spray River formation. To the west, the only semi-permanent land mass was Cascadia, where the Pacific coast now is (Schofield, 1923). This was probably too far away to supply sediment to the Spray River formation. The upper part of the Spray River formation is notable for the amount of zircon and tourmaline present.

These are usually somewhat worn, suggesting long transportation. The most likely source for the derivation of these minerals would be from the Permian and Triassic volcanics of central British Columbia.

Ripple marks were observed in the Sulphur Mountain member of the formation, and ripple marks, mud cracks and rain prints have been reported from the Spray River formation at Banff (Warren, 1927, p. 40). These suggest a shallow-water environment, as stated by Warren.

According to Clarke (1924, p. 220), the order of precipitation of salts from sea water is: iron oxide and calcium carbonate, calcium carbonate and gypsum, gypsum, after which the more soluble salts are precipitated. In the Spray River formation the composition of the beds suggests that such precipitation occurred. The rocks are dominantly carbonates, with considerable iron oxide and some gypsum. Thereis, however, considerable clastic material, which was probably brought in by streams. Consequently, with the addition of fresh water, the concentration of the sea water would not go to completion and only the least soluble materials would be precipitated. Many of the beds are finely banded (Warren, 1927, p. 39). Fossils are quite scarce, except in thin beds where they may be abundant.

The following theory is suggested for the origin of these deposits. The Spray River sea, at least on the eastern side, was shallow, as shown by ripple marks, etc. Streams

flowed into the sea, as shown by the clastic materials, during part of the year, at least. However, evaporation of the sea water was sufficient to keep pace with the additions of fresh water. Iron oxide, calcite and a small quantity of gypsum were precipitated, showing that concentration was moderate. The very fine banding mentioned by Warren may indicate seasonal deposition, in which case it is possible that the streams were seasonal and that in other seasons evaporation was dominant. The rather saline waters would discourage organisms. However, if for some reason, a great influx of normally saline ocean water with its accompanying life were brought in to the site of precipitation, the salinity of the more saline water would be reduced. A storm could act as the agent. With return to normal conditions, evaporation would increase the salinity once again and kill off the life, which would be preserved in a thin fossiliferous layer.

The white beds of the upper part of the Spray River formation contain iron also. The light beds are usually fossiliferous, however. The organic matter would serve to reduce any iron oxide precipitated to the ferrous state, which is light colored. Thus the above explanation appears to fit these beds also.

Allan (1933, p. 633) suggested that at least part of the gypsum deposits in the upper part of the Spray River formation on Mowitch creek were precipitated from sea water in shallow basins.

UPPER GROUP

The upper group of beds considered here consist of the Fernie, Kootenay, Blairmore and Lower Alberta strata. Petrologically these form an essentially conformable group of beds.

Broadly speaking, these show a complete cycle of sedimentation, from the fine grained marine Fernie shales to the fine grained marine Lower Alberta sediments. There is no marked break in the lithology.

Three lines of evidence show that these must be considered together. Grain size increases gradually from the very fine material of which the Fernie shales are composed, to the basal Blairmore conglomerate which represents a maximum. Generally speaking, the grain size then decreases to a minimum in the Lower Alberta shales. This is not correct in detail, of course, but is a general pattern. Paralleling the change in grain size is a change in the amount of dark grains in the beds. These, composed largely of chert and argillite, are at a minimum in the sandstones of the Fernie and increase rapidly through the Kootenay formation to a maximum in the upper part of those beds. There is then a gradual decrease, although throughout the rest of the section rock fragments are more abundant than in the Fernie. The third line of evidence is to be found in a consideration of the feldspars and other minerals of igneous origin. These gradually increase upwards in the Fernie and Kootenay strata and show a marked increase in the upper part of the Blairmore formation (see Table

TABLE V.

Occurrence of Minerals in Mesozoic Rocks of Highwood-Elbow Area

Formation	Spray R.			Fernie		Kootenay		Blairmore				Lower Alberta		
Member	Basal ss.	Sulphur Mt.	Whitehorse	Lower ss.	Upper ss.	Basal ss.	Upper beds	Basal cgl.	Lower Blair.	Upper Blair.	Tuffs	Coarse ss.	Fine ss.	Clay sh.
Pyrite				a	r		a	a	a	r	r			R
Quartz	C	C	C	C	C	C	C	C	C	C	a	a	a	r
Chert			A		A	A	A-C	C	C	c	r	c	c	
Quartzite					A	a	c	c	c	r		c		
Argillite					c	c	C	C	C	c	r	C	a	
Magnetite										R				
Rutile			R						R	R	R		R	
Octahedrite											?			
Carbonates				Present in every formation										
Orthoclase				r	r	a	A		a	C	C		a	c
Microcline										R				
Plagioclase				R						a	A		a	a
Pyroxene			?	R						r	r			
Amphibole										R				
Sodalite											?			
Garnet					R	R			R		R			R
Zircon	r	r	a	r	r	r	r	r	r	r	r	r	r	r
Kyanite						R								
Epidote				?						r	r			
Tourmaline		r	a					r	r	R			R	
Zeolite										R	a			R
Analcite											?			
Muscovite		r	r		r		a	R		r			a	
Biotite				R	r	r	R	R	R	r	r	r	r	A
Chlorite							R			A	a			
Glauconite				?	?									
Kaolinite					?	?	?				?			?
Titanite									R					
Apatite	R			R		r	R	R	R	r				R
Collophanite	a		a											
Gypsum		a	c									r	a	

C - very common
c - common
A - abundant

a - scarce
r - rare
R - very rare

V.) Rutherford (1924, pp.24-28) shows that a similar sequence occurs in the Upper Jurassic and Lower Cretaceous beds of the Nordegg area. The tuffs at the top of the Blairmore formation are not, of course, significant to this discussion.

It has been shown by Tyrrell (1886), Schofield (1923), McLearn (1932), Warren (1938) and others that the Selkirk Mountains were probably the source of this group of sediments. That most of the sediments were derived from the west is shown by the great increase in thickness and the increase in coarseness of the sediments towards the west. The Lower Cretaceous sediments are infolded with the earlier sediments in the Rocky Mountains, there is no angular unconformity between the Paleozoic and Mesozoic sediments and the igneous pebbles and minerals could not have been derived from the Rocky Mountains.

The age of some of the contributing beds in the Selkirk Mountains was probably Paleozoic, as many grains of argillite carry organic forms.

The "transition beds" near the top of the Fernie formation probably represent the first uplift and erosion of the Selkirk Mountains. These beds are probably of early Upper Jurassic age, from the fossil content. Thus, this dates the first uplift of the Selkirks.

The great increase in rock fragments towards the top of the Kootenay formation suggests that large areas of argillites and quartzites were exposed in the Selkirks by this time. A little

fresh orthoclase is present, showing that some igneous rocks were exposed. When the upper part of the Blairmore formation was being deposited, large areas of igneous rocks must have been exposed, for feldspars and other minerals of igneous origin become very abundant.

The conditions of deposition for this group of beds are not clear. The "transition beds" and upper sandstone of the Fernie formation were probably deposited in shallow water near shore. This is shown by minute crossbedding in some of the thin sandstone beds and the presence of plant fragments. Part or all of the massive sandstone may represent a beach deposit. The yellow-weathering bands contain a considerable amount of iron carbonate, which is precipitated in marshes and other shallow water environments (Twenhofel, 1926, p. 331). Since marine fossils occur in some of these lenses, the marshes must have been walt water. Rutherford (1924) and Wallace (1917) have shown that saline solutions are active corrosion agents. The quartz grains in these lenses show considerable corrosion. Therefore, these lenses probably mark salt marshes, due to a temporary recession of the sea, which may have been concentrated slightly by evaporation. The sand as a whole resembles a beach deposit.

The basal sandstone of the Kootenay formation is quite clean and well sorted. The beautiful rounding of the quartz grains and the crossbedding, in addition to the sorting, suggest that part of this sand may have been deposited by wind.

The Kootenay formation was apparently deposited in rather small basins, in fresh water. The basins were shallow, as shown by the ripple marks, ironstone nodules and the accumulations of coal. The presence of well preserved plants which have not been badly broken up, shows that the basins were small and shallow. The lateral variations in the coal and in the beds of sandstone and shale also suggest small basins.

The manner of deposition of the basal Blairmore conglomerate is difficult to reconstruct. If this bed is of the same age throughout, an extensive body of water would be required. However, both the Kootenay strata below and the Blairmore strata above show characteristics of deposition in small bodies of water. This conglomerate represents some unusual condition. Pebbles of the same nature occur in both the Kootenay and Blairmore strata. Therefore, there was no change in the source of the material. There must have been a great increase in the competency of the rivers which transported this material. This could be accomplished either by an increaseof the gradient of the stream by uplift to the west, or by an increase in the amount of water carried by the streams. Since the basin of deposition of this conglomerate was greatly increased in size, this seems to indicate an increase in the amount of surface water. Therefore, a possible explanation for the deposition of this conglomerate is that a change of climate greatly increased precipitation, which resulted in a greatly increased run-off and the formation of a very extensive shallow

lake in which the conglomerate was deposited.

If such a lake was formed, it was short lived, as the beds above the conglomerate by their lenticular nature suggest a return to deposition in small basins. This is particularly marked with the freshwater limestones.

In Blairmore time, the unroofing of large areas of igneous rocks occurred in the source area, probably the Selkirk Mountains, as is shown by the great increase in feldspars, chlorite and other minerals. Previous to this time, small amounts of feldspar were deposited, probably derived from small intrusive bodies above the main igneous masses. The feldspars in the Kootenay formation are generally less decomposed than those in the Blairmore, although perfectly fresh feldspar also occurs in the Blairmore. This may indicate either more rapid erosion or a drier climate at the source, in Kootenay time. The presence of both fresh and altered feldspars and the considerable amount of chlorite, in the Blairmore time, suggests that much of the decomposition of these minerals occurred before deposition.

Volcanic eruptions in late Blairmore time provided a considerable quantity of sediment. Within this area, two types of material were deposited. The tuffs are the most important, from the standpoint of bulk. The brownish arkose in the upper Blairmore (slide #11), which carries abundant euhedral feldspars, was almost surely derived from the volcanics, since long transportation would destroy the crystal forms. The great alteration, however,

suggests that this arkose was derived by erosion of already deposited volcanic rock, with a short transportation by water.

Near the close of Blairmore time, considerable iron was deposited, chiefly as the oxide but also as the carbonate. Some of this was deposited under oxidizing conditions, producing red beds. Part of the iron may have been deposited under oxidizing conditions with later reduction, or it may have been reduced when deposited, thus producing ferrous iron which weathers red, due to oxidation, in the outcrops.

Throughout Blairmore time, the land was low and close to sea level as shown by the marine horizons in the Blairmore formation. At the close of Blairmore time, some erosion may have occurred. In lower Upper Cretaceous time, the sea once again came in and in it was deposited the Lower Alberta formation.

The coarse sandstones near the base of the Lower Alberta formation contain nothing that could not have been derived from the underlying Blairmore formation. The pebbles and mineral constituents are very similar. It is probable that the Blairmore beds acted as the source for these sandstones.

The clay-shales higher in the Lower Alberta formation are probably related to the Crowsnest Volcanics. This is indicated by the orthoclase feldspars with Baveno twinning, which is characteristic of the orthoclase of the volcanics (Rutherford, 1938). The sharpness of the crystals of zircon and biotite found in these shales also suggests that transportation was short.

The alteration of the mica in these beds, with fresh mica in the same beds, suggests that possibly some of the material was derived by erosion from pre-existing deposits, while some of it is probably tuffaceous. This is shown by a few chards of volcanic glass.

APPENDIX

Description of Slides

APPENDIX - DESCRIPTION OF SLIDES

SPRAY RIVER FORMATION

Basal Sandstone (Slide #5)

Megoscopic: Hard, dark grey sandstone, cut by oolite veinlets. Occasional pockets of shaly material.

Microscopic: Calcareous sandstone, with average diameter of grain 0.09 mm. The grains are well-sorted with respect to size. (See Plate XVII A).

The composition of this rock is approximately:

Detrital:
- Quartz 70%*
- Zircon
- Apatite
- Argillaceous material and collophanite 5%

Authigenic:
- Calcite 25%
- Quartz

The most important constituent is quartz. The grains are angular and interlocked, and some show dust rims within the grains, due to regrowth. Original shape was rounded to sub-rounded. Some grains are clouded by brown or dark grey linear inclusions. Undulatory extinction is common.

Calcite is abundant, filling interstices and also as veins. It is rarely cryptocrystalline. Twinning is abundant in the larger grains.

About 5 per cent of the slide is composed of a brown isotropic mineral with index of refraction close to 1.54, which is probably a phosphate allied to collophanite. Chemical tests show the presence of a little phosphate in the rock.

Heavy minerals are very rare. Zircon occurs in rounded grains. Apatite, also in rounded grains, is extremely rare. A little argillaceous material is present, both interstitially and as small aggregates. It is usually brownish and somewhat resembles the collophanite. Of fairly common occurrence are groups of very fine grains of a colorless, anisotropic mineral, the index of which is greater than 1.54. No grains large enough to identify were found. One-half of a brownish spherulite is present, showing a very clear black cross between crossed nicols. The material of w which this is composed is not known.

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*The percentage of quartz includes authigenic quartz.

FERNIE FORMATION

Upper Sandstone (Slide #12)

Megascopic: Fairly soft, light brown weathering, dark brown sandstone.

Microscopic: This rock consists of quartz, argillite and chert, cemented by a regrowth of the quartz grains, and carrying some iron oxide which is probably responsible for the brown color. The average grain size is 0.1 mm. (See Plate XVII B).

Composition:

Detrital:
- Quartz 40%
- Chert 30%
- Argillite 25%
- Quartzite
- Zircon
- Vesuvianite?
- Clay material

Authigenic:
- Quartz
- Calcite
- Iron oxides
- Pyrite
- Glauconite?

Quartz makes up about 40 per cent of the rock. It is quite clear, rarely clouded with inclusions. The grains are angular, but dust rims show that this is due to regrowth. Originally, the shape was well rounded.

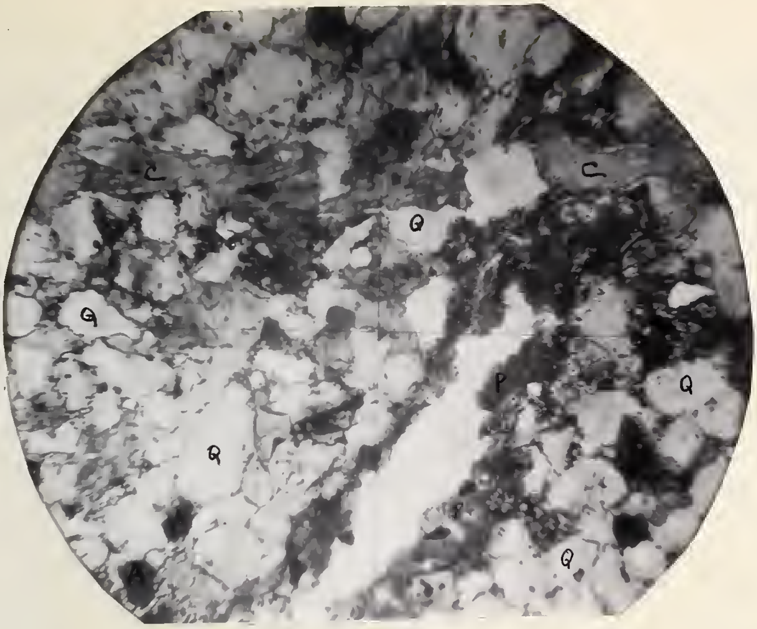
Slightly brownish grains of chert make up about 30 per cent of the rock. These are cryptocrystalline, but not radiating. A very small amount of chalcedonic silica is present.

Dark brown to almost black grains of argillite are abundant and make up about 25 per cent of the rock. These are not so well rounded as the original shape of the quartz. These grains are almost opaque and polarize slightly. Occasionally a few small quartz grains are carried by the argillite.

Fine quartzite is present in minor quantities. Zircon and vesuvianite? are present in very small quantities. One blue-green composite grain is present which may be glauconite. Some calcite is present, but is not important as a cementing agent. Iron oxide, probably a low hydrate, is quite common and frequently forms a film between grains of quartz. Brownish limonite is also present. A very small amount of pyrite was observed. A little argillaceous material occurs interstitially. Some sericite appears to be present in this material.

Plate XVII. A. Slide 5. Basal Spray River sandstone, P, phosphate (collophanite?); C, calcite stringer; Q, quartz; A, "argillite". x64

B. Slide 12. Upper Fernie sandstone. Q, quartz; A, argillite. Note regrowth of grain X. x36



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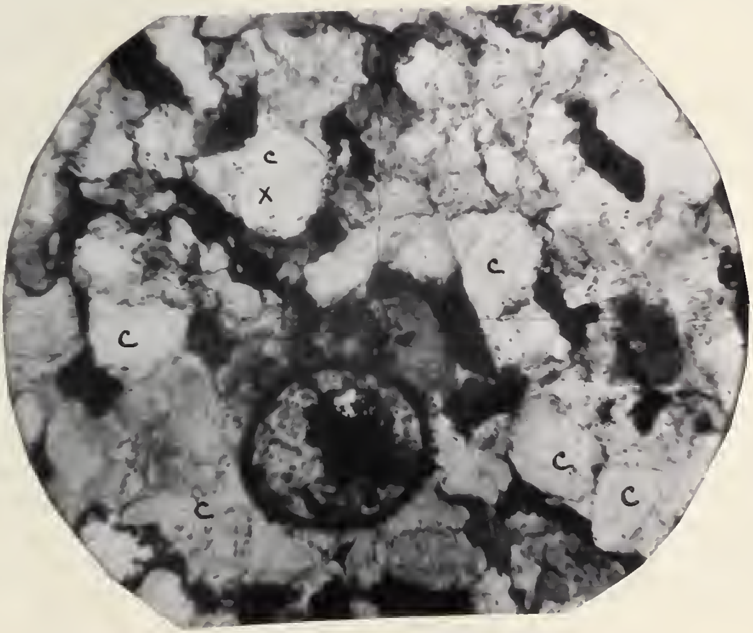


B

FERNIE FORMATION
Yellow-weathering Lense in Upper Sandstone (Slide #22)

Megascopic: Hard, dark grey, fine-grained, dense, bright yellow-brown weathering sandstone. Sometimes carries marine fossils.

Microscopic: This rock consists of highly angular quartz grains set in a matrix of opaque, dark grey to dark brown, fine-grained material. The maximum diameter is 0.2 mm. but averages about 0.1 mm. (See Plate XVIII A).

The composition of the rock is:

Detrital:
Quartz 55%
Chert)
Argillite) 5%
Zircon
Biotite
Garnet

Authigenic:
Carbonate (siderite?)
Iron oxides

Matrix 40%

Quartz makes up about 90 per cent of the larger grains and about 55 per cent of the rock. The quartz is extremely angular and frequently occurs in long narrow fragments. The edges of the grains are very irregular, probably due to corrosion. The grains rarely touch.

Chert and argillite are rather scarce but make up almost 5 per cent of the rock. These are usually slightly brownish, the argillite grains being the darker. Like the quartz, these grains are very angular.

Zircon is rare, and garnet and biotite are very rare.

Calcite or some other carbonate occurs as large authigenic grains and also in the matrix.

The matrix makes up about 40 per cent of the rock. It is dark grey in color, but in the weathered part of the slide is dark reddish brown. It is almost opaque. A careful examination shows that there is considerable very fine carbonate and considerable unidentifiable clay material. Iron is present, as it is the coloring agent in the weathered portion. This iron is probably present as the carbonate, siderite.

A few indistinct plant fragments occur in the matrix.

KOOTENAY FORMATION

Basal Sandstone, Light Phase (Slide #9)

Megascopic: Hard, light grey, medium grained sandstone.

Microscopic: This sandstone is largely composed of quartz, chert and rock particles. It is quite well sorted. The average grain size is 0.2 millemeters, but reaches 0.4 millemeters. (See Plate XVIII B).

The composition is as follows:

Detrital:
- Quartz 70%
- Chert)
- Argillite) 29%
- Quartzite)
- Orthoclase
- Zircon
- Biotite
- Kyanite

Authigenic:
- Quartz
- Kaolinite?

Quartz occurs in large angular regrown grains. The original grains, as shown by dust rims, were very well rounded. Most of the quartz is clear, but some of it shows bands clouded by inclusions.

The rock particles, chert, quartzite and argillite, are well rounded. The argillite fragments are brown to dark brown, while most of the chert and quartzite is colorless.

Orthoclase is present in somewhat altered grains. It is not abundant.

Zircon occurs in subangular grains up to about 0.05 mm. in diameter. Only one grain of biotite was found. The kyanite is in grains about 0.1 mm. in diameter. Its optical properties check with those of kyanite.

The material referred to as "kaolinite?" has been described in Chapter III, in the section dealing with the basal Kootenay sandstone.

This is a very clean sandstone, with little interstitial material.

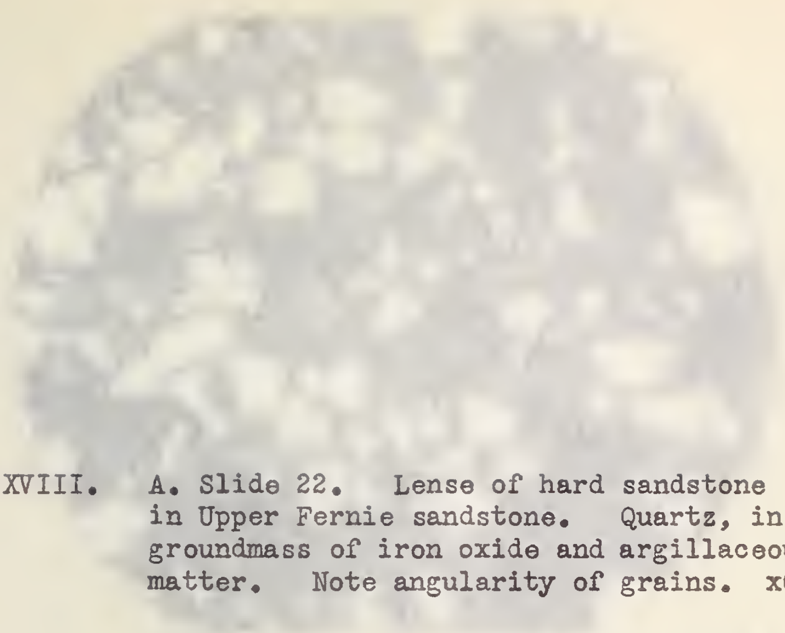
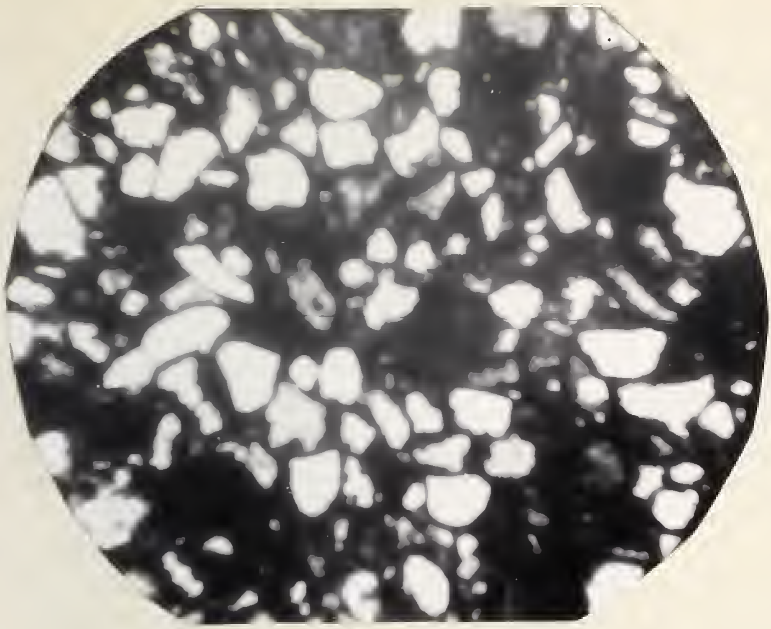


Plate XVIII. A. Slide 22. Lense of hard sandstone in Upper Fernie sandstone. Quartz, in groundmass of iron oxide and argillaceous matter. Note angularity of grains. x64

B. Slide 9. Basal Kootenay sandstone, light phase. Q, quartz; A, argillite. Note marked dust rims on some quartz grains. x64



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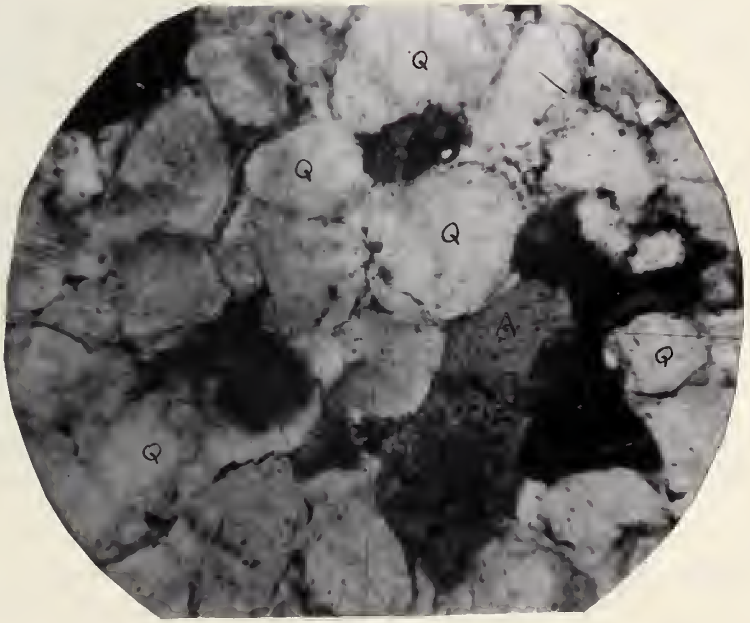


B

KOOTENAY FORMATION

Basal Sandstone, Dark Phase (Slide #10)

Megascopic: Hard grey medium grained pepper and salt sandstone. Light and dark beds alternate, due to variations in the quantity of dark grains.

Microscopic: This sandstone is largely composed of quartz, chert and argillite, cemented by quartz. The principal difference between this dark phase and the light phase of the basal sandstone lies in the greater amount of argillite in the dark phase. The average grain size is 0.23 mm. and the maximum is 0.35 mm.

The composition is:

Detrital:
- Quartz 48%
- Chert)
- Argillite) 50%
- Quartzite)
- Clay material

Authigenic:
- Quartz
- Kaolinite? 1%

The quartz occurs in angular grains showing marked dust rims in some cases, showing that regrowth has occurred. Most of the quartz is clear. A few grains carry inclusions that resemble zircon.

Some of the chert is chalcedonic. The chalcedony may occur either as fine small fibrous groups in a grain of chert, or may occur in a much larger group which is a grain in itself. The argillites are brown, as usual, except for one grain which is greenish. Silicified forms, which are probably organic, are present in some of the argillite. Sericite is present in some of the argillite grains.

The kaolinite? is quite abundant and makes up about 1 per cent of the slide. The individual crystals never exceed 0.03 mm. in diameter.

This slide contains a little more clay-like interstitial material than does Slide #9.

Heavy minerals appear to be entirely absent.

KOOTENAY FORMATION

Sandstone 275' Below Top (Slide #15)

Megascopic: Dark brownish grey, fine grained, finely bedded, sandstone. Weathers light grey-brown.

Microscopic: This sandstone is marked by a large percentage of argillite and a smaller percentage of quartz, while carbonaceous matter is present. The average grain size is 0.11 mm.

The composition is:

Detrital:
- Argillite) 70%
- Chert)
- Quartz 20%
- ?Calcite
- Zircon
- Muscovite
- Carbonaceous matter 6%
- Clay material

Authigenic:
- Quartz
- Calcite 3%
- Pyrite
- Limonite

The argillite grains are very plentiful and vary from brown to almost black in color. Silicifed organic forms are present in some particles. A few grains are cut by narrow veinlets of quartz. Chert occurs both as finely crystalline silica and as chalcedonic silica. Some of it carries crystals of magnetite. The rock particles reach 1.5 mm. in diameter, but are usually less than 0.3 mm.

The quartz sometimes shows evidence of regrowth. The grains are usually smaller than the rock fragments. The calcite occurs in rhombs about the same size as the other grains. The edges of the rhombs are frequently irregular. Some of this calcite may be detrital.

A little fairly fresh orthoclase is present. Zircon and muscovite are rare.

Pyrite is present in small quantities. Some of it has altered to limonite.

Indeterminable carbonized plant fragments are present. Small pieces are difficult to differentiate from dark argillite.

There is an appreciable amount of fine-grained clay material in interstices.

KOOTENAY FORMATION
Sandstone 183' Below Top (Slide #23)

Megascopic: Fairly hard dark, coarse, grey sandstone, made up almost entirely of black grains.

Microscopic: This rock is made up almost completely of argillite, with less chert and a small quantity of quartz and orthoclase. The average grain size is between 3.5 and 4 mm., but the sorting is not good and many grains are less than 1 mm. (See Plate XIX).

The composition is:

Detrital:

Argillite	50%
Chert	30%
Quartz	15%
Orthoclase	4%
Apatite	

Authigenic:
- Quartz
- Calcite
- Kaolinite?
- Pyrite

The argillite and chert grains are subangular to subrounded. The argillite is light to dark brown in color and is sometimes almost opaque. Many of the grains are cut by quartz veins. Some of the grains carry organic forms, of which there are three types. Some of them resemble crushed plant tissue. Another type, which is usually silicified, is circular and may represent sponge spicules. The third type consists of a reticulate form.

The chert is almost clear to slightly brownish. Most of it is a very fine grained aggregate, but some chalcedonic chert is present. One broken spherulite of chalcedony was observed.

Quartz is angular, but many grains show, by the presence of dust rims, that the angularity is due to regrowth. The original shape of the quartz was well rounded, thus contrasting with the less well-rounded argillite.

Orthoclase is present in only slightly altered grains. Apatite is very rare.

Calcite occurs sparingly and appears to have been introduced into interstitial spaces. Kaolinite? occurs in aggregates of crystals. Pyrite is present in cubes, some of which are altered to limonite.

KOOTENAY FORMATION
Sandstone 160' Below Top (Slide #24)

Megascopic: Hard, dark grey, fine grained sandstone.

Microscopic: A calcareous sandstone with abundant chert and argillite, and some carbonaceous material. The average grain size is 0.14 mm. Grains are angular to subrounded. Regrowth of the quartz grains has increased the angularity of these.

The composition is:

Detrital:	Authigenic:
Quartz 40%	Quartz
Chert 20%	Calcite 15%
Argillite 15%	Limonite
Orthoclase 5%	
Carbonaceous matter 5%	
Muscovite	
Zircon	

The quartz shows some regrowth, but not much. Only a few dust rims are present. A few grains show undulatory extinction.

The chert is principally fine-grained, with very little chalcedonic silica. It is usually colorless.

The argillite and carbonaceous matter cannot be surely distinguished from each other, as both are brown and frequently almost opaque.

Orthoclase is quite fresh. Muscovite and zircon are very rare.

Calcite is abundant and is probably as important as the authigenic quartz as a cementing agent in this rock. Limonite occurs as brownish stains.

KOOTENAY FORMATION

Sandstone 128' Below Top (Slide #16)

Megascopic: Very fine grained, almost black, finely bedded sandstone.

Microscopic: Very fine calcareous sandstone or coarse siltstone, consisting of quartz, argillite, chert, with considerable carbonaceous matter. The average grain size is 0.06 mm. The bedding of this rock is due to alternating finer and coarser layers, and to an increase in the carbonaceous matter in the finer layers. The grains are angular. (See Plate XIX B).

The composition is as follows:

Detrital:	Authigenic:
Quartz 30%	Calcite 30%
Argillite and carbonaceous matter 30%	Limonite
Chert 5%	
Fine clay material	

Due to the fineness of grain size, it is difficult to separate orthoclase from quartz in this slide. Some orthoclase is believed to be present, however, from the shapes of some of the grains.

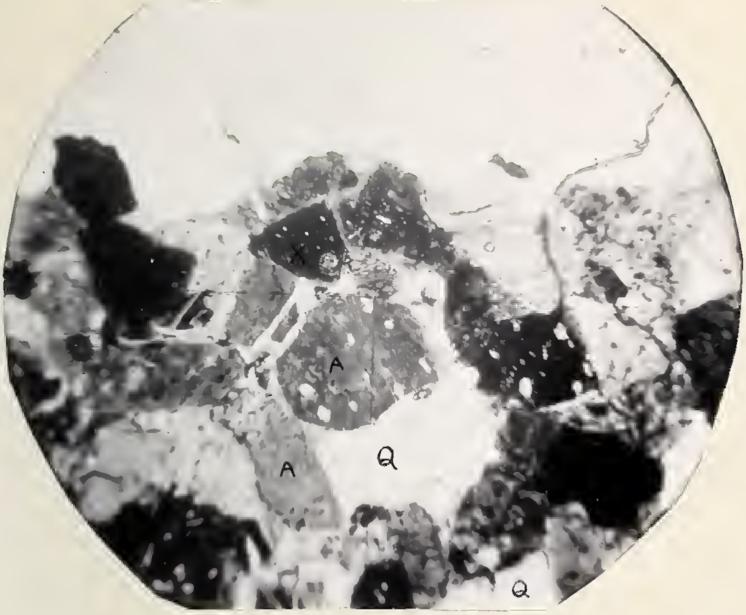
The clastic grains are not closely packed, but touch, in most cases, while calcite fills the interstices.

Some very fine material, probably clay, is present in the slide and frequently clouds the calcite.

Thin shreds of a micaceous mineral are present. These have been referred to sericite.

Plate XIX. A. Slide 23, Kootenay sandstone. Q, quartz, A, argillite. Note coiled organic form in grain X. x36

B. Slide 16, Kootenay sandstone. C, calcite; Q, quartz; A, argillite. x64



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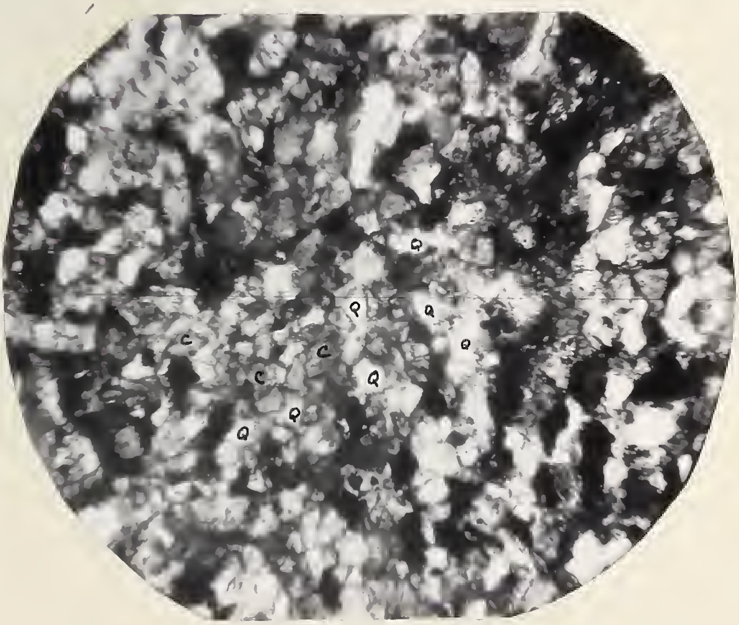

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KOOTENAY FORMATION
Sandstone 81' Below Top (Slide #8)

Megascopic: Dense, fine grained, dark grey sandstone or siltstone.

Microscopic: This is a siltstone, with angular quartz grains averaging 0.03 mm. in diameter, but up to 0.1 mm. The matrix is brownish in color and consistsof a clay material. Sorting is poor. Lamination occurs, due to varying proportions of quartz and clay.

The composition is:

Detrital:
- Quartz 30%
- Chert and argillite 15%
- Carbonaceous matter 15%
- Clay material 40%
- Zircon
- Hornblende

Authigenic:
- Sericite?
- Limonite

The quartz grains are very angular as would be expected in this fine-grained rock. Some of the clear grains may be orthoclase. Chert and argillite are present. The argillite is apt to be confused with carbonaceous matter.

Fine-grained, barely anisotropic clay material forms the matrix of the rock. It is brownish in color, probably due to included organic matter. Shreds of a colorless mineral with fairly high birefringence are imbedded in it and have been referred to sericite.

One grain each of zircon and hornblende were found. These two grains are about the same size as the quartz grains. The hornblende was identified by pleochroism and birefringence.

This rock shows very poor sorting.

KOOTENAY FORMATION

Cannel (Slide #2)

Microscopically, the cannel coal is almost opaque, except in the thinner parts of the slide, where it is reddish brown by transmitted light. In reflected light, it is dark brown.

Organic forms are few and are not well preserved. These appear to represent bits of plant tissue.

The great part of the cannel is made up of a very finely granular yellowish brown substance, which is translucent and isotropic. It appears to represent organic matter which has undergone sufficient decay to destroy all organic form.

A few extremely fine anisotropic grains, which look like quartz, are present. These are arranged in lines which probably represent bedding. The material when analysed (see Chapter VII) showed about 10 per cent ash. These grains, however, do not amount to more than 1 per cent of the material, so that most of the ash is probably in a finely divided state.

High Ash Cannel (Slide #4)

Megascopic: Dark grey, white weathering siltstone with flakes of carbonaceous matter.

Microscopic: A carbonaceous siltstone with the largest clastic grains not exceeding 0.04 mm. in diameter. The groundmass consists of black to brown very fine grained clay and carbonaceous matter. Organic forms are abundant.

The clastic grains appear to be largely quartz, which is very angular. Sericite and zircon were observed, but both are very rare.

Organic matter is present in three forms. The commonest is a structureless material, as described in the cannel. Also common are carbonized fragments of plant tissue, which reach 3 mm. in length. These probably represent shreds of leaves or bits of bark. Pollen grains are fairly abundant. The pollen grains are about 0.03 mm. in diameter. The shape is usually "teardrop". The cell wall is brownish, as is the interior. The wall, however, is slightly less transparent and consequently can be seen. Some of the pollen grains are crushed.

BLAIRMORE FORMATION

Shaly Sandstone (Slide #13)

Megascopic: Dull green, fine-grained, shaly sandstone, with which is associated brown weathering calcareous nodules (See Slide #17).

Microscopic: A sandy siltstone, with a maximum grain size of 0.12 mm. and an average of about 0.7 mm. for the larger grains. These are in a fine-grained groundmass. The grains are angular.

The composition is:

Detrital:
- Orthoclase
- Plagioclase
- Quartz
- Magnetite
- Zircon
- Apatite
- Rutile
- Chlorite
- Pyroxene

Authigenic:
- Calcite
- Pyrite
- Sericite
- Zeolite?

Of the detrital minerals, orthoclase is the most common. This makes up most of the larger grains. The orthoclase is usually fresh, but is sometimes somewhat altered. Plagioclase, about Ab80An20 in composition, is present in much smaller quantities. It is also fresh.

Quartz is present, apparently in small quantities. It is fairly angular. Rock fragments were not identified.

Chlorite is present throughout the slide and is responsible for the green color of the rock. Zircon is fairly abundant, but the grains are very small. Apatite occurs in elongate prisms. Rutile is very rare. Magnetite is not uncommon, as irregular grains. A few grains of a colorless orthorhombic pyroxene are present.

Calcite occurs in small irregular grains throughout the slide, but is not abundant. Pyrite is quite rare, but shows crystal form. Sericite occurs as shreds. A brownish, anisotropic material occurring in aggregates apparently filling cavities, has been provisionally identified as a zeolite. It shows moderate relief and yellow interference colors of the lowest order.

BLAIRMORE FORMATION

Calcareous Nodule (Slide #17)

Megascopic: Chocolate-brown weathering, greenish grey, dense nodular sandy limestone. This bed is associated with the shaly sandstone described on the previous page.

Microscopic: This slide consists of calcite in fine crystals, with scattered grains of orthoclase and other minerals. There are occasional coarse crystals of calcite.

The composition is:

Detrital:
- Orthoclase
- Plagioclase
- Chlorite
- Pyroxene
- Biotite
- Quartz?

Authigenic:
- Calcite 75%
- Zeolite?

The feldspars are fresh, but quite fine grained, with a similar size range as in Slide #14. The grains are angular. Quartz was not definitely identified, but may have been confused with orthoclase.

The other detrital minerals are quite similar to the detritals of Slide #14. Biotite is the only mineral found in Slide #17, that was not found in Slide #14. Zircon, apatite, rutile and magnetite, found in Slide #14, were not identified in Slide #17.

The calcite in this slide is usually fine grained, without marked crystal boundaries. Extinction is indistinct. A few large crystals are present. These show twinning. In a few places, the calcite is spherulitic. These spherulitic aggregates reach 1 mm. in diameter.

There is also some extremely fine unidentifiable clay material.

BLAIRMORE FORMATION
Arkose (Slide #11)

Megascopic: This rock is light grey brown, fairly soft, coarse to medium grained, arkosic sandstone. (See Chapter IV, for a discussion of this bed).

Microscopic: This rock consists of feldspar euhedra, and grains, augite crystals, rock fragments and a dense fine grained groundmass. The grain size varies from 0.8 mm. downwards, with an average sice of about 0.5 mm. (See Plate XXA).

The composition of this slide is:

Detrital:	Authigenic:
Orthoclase 40%	Pyrite
Augite 3%	Part of groundmass
Microcline?	
Chlorite	
Biotite	
Argillite) 5%	
Chert)	
Tuff 10%	
Magnetite	
Part of groundmass 40%	

The feldspars in this slide usually show crystal form. Square prisms and elongate prisms are the commonest. Most of the feldspars are orthoclase and sanidine. Baveno twinning and Carlsbad twinning are present. All the grains are altered, some almost completely. The form of the grains is usually diagnostic. One grain of feldspar showed grating-structure and may be microcline. Many of the crystals are zoned.

Augite is also present in green crystals, which generally show both prism and pinacoid faces. The grains are badly cracked and somewhat altered.

Chlorite is present in a small quantity. One crystal showing the feldspar outline has been replaced by a dull green, non-pleochroic material, which may be chlorite or a serpentine.

Chert and argillite are present in large grains, but there are few of these. They are sometimes difficult to distinguish from fragments of tuff.

Arkose (Slide #11) continued

Magnetite occurs in some of the fragments of tuff.

The glass in the slide occurs as detrital fragments of consolidated tuff, deposited like a normal clastic and not as volcanic ash. Chard shapes are preserved in some of these fragments. One piece of tuff was observed carrying a large feldspar crystal.

Biotite is present as small flakes.

The groundmass of the slide is a dark grey to dark green, very fine grained material, which may be partly glassy. It is probable that most of it represents soft decomposition products of the feldspars and other minerals, which were deposited contemporaneously with the other grains of the rock. Part of the groundmass may consist of authigenic decomposition products.

Pyrite in irregular grains was the only definitely authigenic mineral recognized.

This rock must have been derived from a source near at hand, by normal processes of erosion. It probably represents erosion products from the Crowsnest Volcanics.

BLAIRMORE FORMATION
Green Arkose (Slide #6)

Megascopic: This is a dark green, dense arkosic sandstone. Flakes of biotite are abundant. This rock was collected from a bed about 200 feet below the top of the Blairmore formation.

Microscopic: The slide is composed of angular and fresh orthoclase and plagioclase, quartz, quartzite, chert, argillite and other minerals and rock fragments, averaging 0.18 mm. in diameter, set in a fine grained greenish groundmass. (See Plate XX B.)

The composition is:

Detrital:
- Orthoclase 25%
- Plagioclase 20%
- Quartz 10%
- Quartzite)
- Chert) 25%
- Argillite)
- Altered biotite 5%
- Microporphyry
- Enstatite
- Actinolite
- Amphibole, altered
- Chlorite
- Fine grained greenish groundmass 12%

Authigenic:
- None recognized

The feldspars make up a large part of the coarser grains. Both orthoclase and soda plagioclase are present, the former predominating. They are usually fresh, but may be altered. The grains are cleavage fragments and do not preserve the crystal form.

Rock fragments are quite abundant. In addition to the usual chert, quartzite and argillite, there are grains with a microporphyritic texture, consisting of minute laths that look like feldspar crystals in a very fine grained groundmass.

A green pleochroic micaceous mineral is very abundant. The pleochroism is light green to dark green. This is probably altered biotite. The grains are bent around the other clastic grains, so that no figure could be obtained.

Green Arkose (Slide #6) Continued

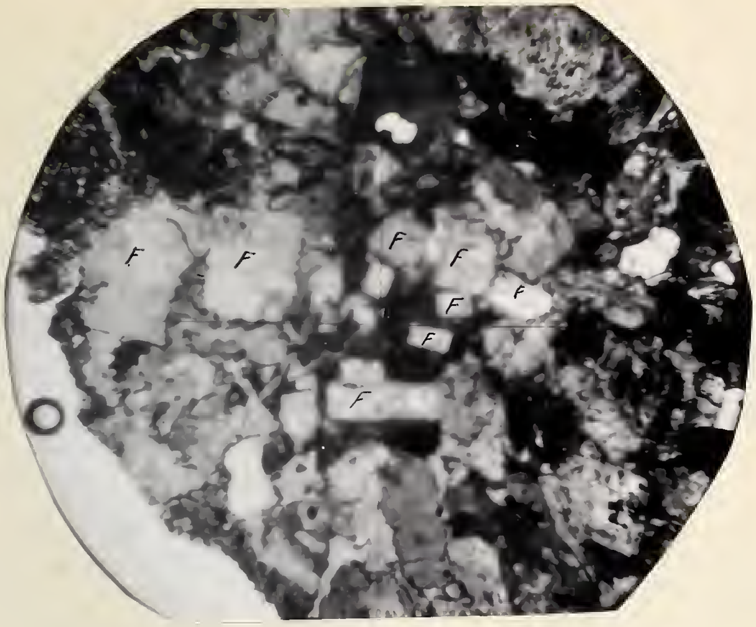
There are at least three species of minerals of high relief. These have been referred to enstatite, actinolite and altered amphibole. Most of the grains of these minerals have suffered some decomposition and fracture.

An unknown mineral occurs in this slide. This mineral is salmon pink to colorless. The index is slightly below that of orthoclase. Maximum birefringence is just about the same as that of quartz. The grains are too small to obtain the other optic properties.

The groundmass of the rock is dirty green in color. It is very fine grained. A thin film of this material surrounds most of the larger grains. Much of this groundmass may be chlorite.

Plate XX. A. Slide 11. Blairmore arkose. F, feldspar; A, argillite; C, fine grained aggregate of chlorite, sericite, etc. Note sharp crystal form showed by feldspars. x36

B. Slide 6. Blairmore arkose. F, feldspar; B, Biotite; A, argillite, in a fine-grained aggregate groundmass. x36



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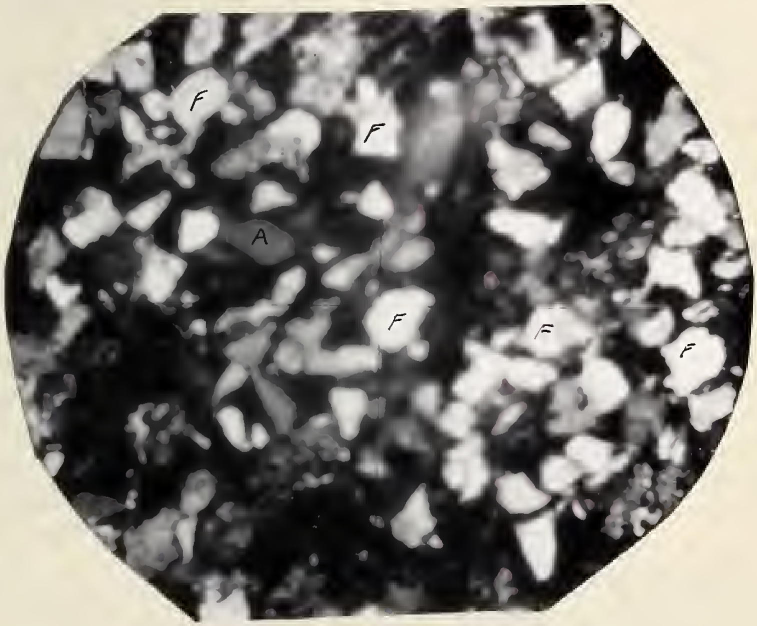


B

BLAIRMORE FORMATION
Tuff (Slide #7)

The tuffs described here from the Blairmore formation are all from the upper 150 feet of beds of that formation.

Megascopic: Hard, dark green, dense rock which develops a coating of pink powder on weathered surfaces.

Microscopic: This rock consists of angular grains of quartz, rock fragments and feldspar in a brownish dense groundmass. Calcite is quite abundant.

The composition is:

Detrital:	Authigenic:
Quartz 20%	Calcite 10%
Chert and argillite 10%	Quartz
Orthoclase	
Plagioclase	
Zircon	
Titanite	
Devitrified glass 60%	

The quartz occurs in angular grains averaging 0.08 mm. in diameter, but with many grains much smaller. The angularity suggests feldspar, but most of the grains show uniaxial figures. Chert and argillite is present in grains up to 0.2 mm,,but u usually less. Pyrite occurs in one argillite grain.

Orthoclase and plagioclase are not abundant. The grains are unaltered. One grain of orthoclase with Baveno twinning was observed. Zircon is of rare occurrence, in rounded grains much smaller than the quartz grains. One very small grain of a mineral identified as titanite was found.

Calcite is quite widespread, as cavity fillings, as a vein and generally disseminated through the slide. A few of the cavity fillings have the centre filled with authigenic quartz.

The groundmass is a dense, olive-brown, very fine grained material, which is almost completely isotropic. Although no chards were observed, this is believed to be partly devitrified volcanic glass.

BLAIRMORE FORMATION

Tuff (Slide #14)

Megascopic: This is a fine grained, dark grey, dense rock, with small cavities filled with white to brown minerals.

Microscopic: This slide consists largely of brownish devitrified glass, with some clastic quartz grains and large cavities filled with calcite, zeolite and chalcedony. The clastic grains are usually about 0.7 mm. in diameter. (See Plate XXIA).

Only a few minerals were noted. Quartz is the most abundant clastic constituent. The grains are highly angular. No feldspar was identified, but some of the grains may be orthoclase. One grain of analcite was found, partially replaced by calcite. Zircon, showing crystal outline, is rare. One grain of hornblende was found.

The filled cavities in this slide are very interesting. These are usually elongate. Normally, three minerals occur. Lining the wall is zeolite. Within this may be a thin layer of calcite, although this is not always present. The interior is filled with banded chalcedony. If the zeolite layer is absent, calcite lines the walls of the cavity.

This zeolite, so-called, is a brownish mineral, non-pleochroic, which characteristically occurs as aggregates, of very fine crystals. Its birefringence is quite low, while its refringence is slightly higher than that of chalcedony. It shows a crude "brush" between crossed nicols, showing that there is an approach to radial arrangement of the crystals.

The great bulk of the slide is composed of devitrified glass. Part of the material is very weakly anisotropic. Some is isotropic. It is grey-brown in color. Large numbers of ovoid and round bodies, slightly denser and browner than the glass, are present throughout. A little iron oxide is also present. No chards were observed.

BLAIRMORE FORMATION

Tuff (Slide #18)

Megascopic: Fairly hard, greenish grey, fine grained rock, with a few grey to olive-grey shaly inclusions.

Microscopic: This tuff is almost all devitrified glass and calcite with only about 15% of clastic grains. The clastic grains consist of angular grains of quartz and orthoclase, with a little zircon. Some of the orthoclase is penetrated by calcite along the cleavages.

Calcite is quite abundant in the slide, but is in a finely divided state. The calcite grains usually include considerable of the fine-grained devitrified glass. Anisotropic material in very fine shreds in the devitrified glass may also be calcite. Calcite probably makes up 10 per cent of the slide.

The thinner portions of the slide show that the rock is very finely bedded. The devitrified glass is quite similar to that in the other slides of the tuffs and its description need not be repeated here. However, on the thin edges of the section, irregular lines in the mass may be the edges of chards.

Tuff (Slide #20)

Megascopic: Olive-green, pink-weathering tuff, with some sand grains apparent.

Microscopic: This is a sandy and calcareous tuff. Clastic grains make up about 25% of the slide, while calcite makes up about 15%.

Orthoclase seems to be the principal mineral present. Some of this has a very low 2V, and belongs to the variety sanidine. Calcite frequently crystallizes about the edges of the grains. Some quartz is present, but in a lesser amount than the orthoclase. Zircon is not rare. The clastic grains reach a maximum size of 0.2 mm., but average about 0.1 mm. One isotropic grain, showing two sets of cleavage lines at right angles to each other, was found. This mineral probably belongs to the sodalite group. Calcite is quite abundant. It frequently penetrates feldspar grains along the cleavages. It also occurs as irregular grains and finely disseminated in the groundmass. The zeolite previously described is present. No well-defined cavity fillings occur in the slide, however. The groundmass is devitrified glass, as described previously. On thin edges, there is a slight indication of chard structure.

BLAIRMORE FORMATION

Tuff (Slide #21)

Megascopic: Dark green, fairly hard sandy tuff, with a few filled cavities.

Microscopic: Feldspar and quartz grains, averaging 0.05 mm. in diameter, in a green, fine-grained, tuffaceous matrix. (See Plate XXI B). Zircon is fairly abundant. A few grains of a pyroxene are present. The pinkish material described under Slide #6 occurs.

The clastic grains are generally very angular. Due to the fineness of grain, it is almost impossible to differentiate between quartz and feldspar. Both are probably present, but the quartz is believed to be dominant. These grains make up about 40 per cent of the slide.

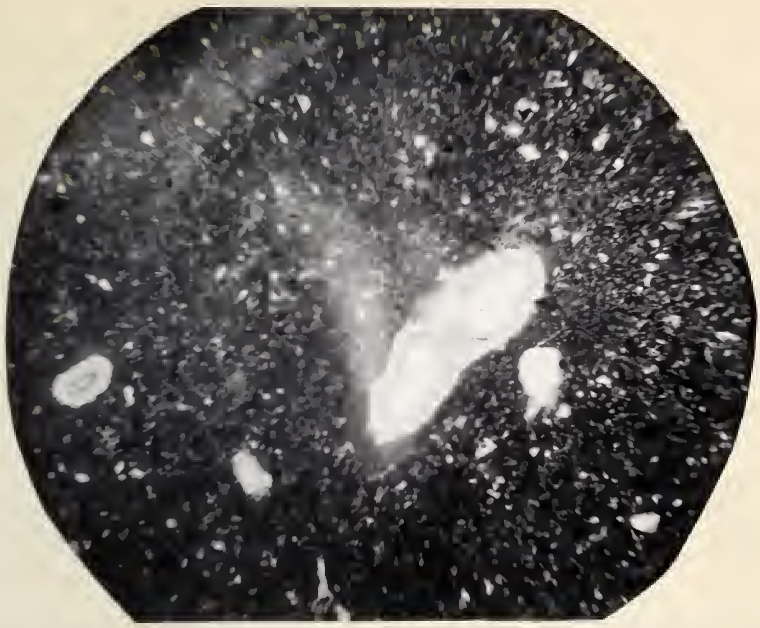
Calcite is entirely absent.

Several cavity fillings are present. Some of these are composed of zeolite entirely. Others carry irregular bodies of chalcedonic silica. Invariably associated with the silica in this slide is a slightly pleochroic green mineral. This material shows limited aggregate polarization with low interference colors. It is possibly chlorite.

The groundmass of devitrified glass is quite similar to that described previously, except that it is green. Parts of it are feebly anisotropic, while some parts appear to be entirely isotropic. It carries abundant minute granules of unknown composition. Part of the green color is due to the presence of small green rod-shaped crystals.

Plate XXI. A. Slide 14. Blairmore tuff. Banded chalcedonic quartz filling cavities in a dense fine-grained groundmass. x 36

B. Slide 21. Blairmore tuff. Small feldspar and quartz grains in a fine grained devitrified glass groundmass. Large cavity in centre filled with quartz, Q; calcite, C; and zeolite, Z. x 36



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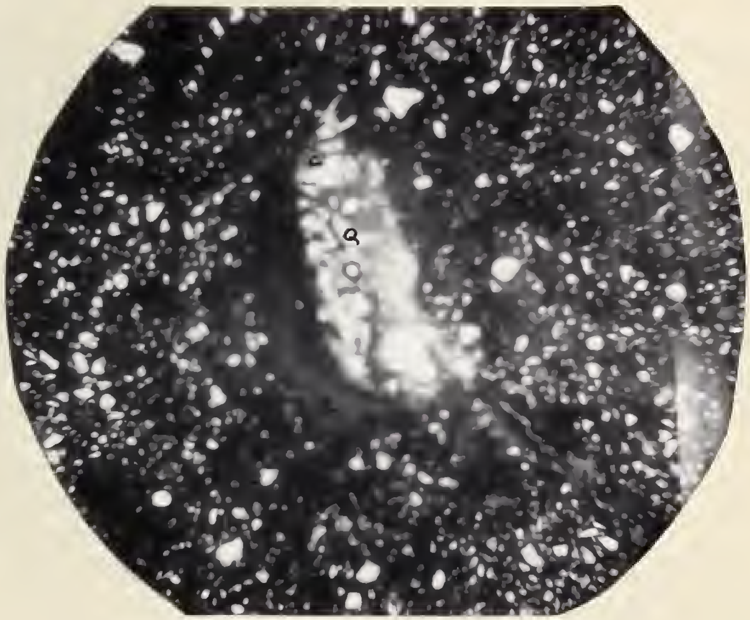


B

BLAIRMORE FORMATION

Oolitic Siderite (Slide #19)

This material was found on Highwood river, one and one-half miles above the mouth of McPhail creek. It occurs 175 feet below the top of the Blairmore formation.

Megascopic: This material occurs in a lenticular bed. It is green on the fresh surface and weathers bluish purple. It is finely oolitic. The rock is fairly heavy.

Microscopic: The slide consists of abundant oolites set in a fine-grained brown groundmass. Small angular grains of quartz, up to 0.08 mm. are present both in the groundmass and in the oolites. (See Plate XXII A.)

The groundmass is very fine grained and resembles the devitrified glass described under the tuffs. It may be tuffaceous. It is mostly feebly anisotropic. Finely divided carbonate is quite abundant. Minute green rod-shaped crystals occur in the groundmass.

The oolites are composed of a carbonate mineral which, from the amount of iron indicated by the weight and weathering of the material, is probably siderite. In ordinary light the oolites show a pronounced relief brush parallel to the lower nicol. Under crossed nicols, the characteristic black cross is very plain, showing that there is a radial structure.

In addition to the radial structure, there are concentric bands. Two principal zones are apparent. The inner consists of very finely crystalline siderite and makes up from one-half to two-thirds of the diameter of the oolite. The outer zone is much more coarsely crystalline, with the individual crystals distinguishable under the microscope. The contact of the two zones is quite regular and is marked by a very narrow brown line. The outer surface of the outer zone is very irregular. In addition, the inner zone usually shows banding due to color change. The centre of the inner zone is usually light grey in color, unless stained by iron oxide. About three-quarters of the radius, from the centre, a narrow brown band occurs. Outside of this, the inner zone again is light grey. The color banding is sharp. The brown band forms an irregular line which tends to be circular.

Oolitic Siderite (Slide #19) continued

Partially oxidized pyrite cubes are always present within the inner zone and are very rare in the outer zone. These pyrite crystals may be concentrated near the centre of the oolite or distributed near the brown band. Sometimes they are scattered haphazardly through the inner zone. Oxidation of the pyrite to limonite has stained the centres of some of the oolites to a much darker color than they usually show.

As many of the oolites are not cut through the centre, groups of the coarser crystals of the outer zone are present in the slide, without any sign of the inner zone.

The maximum diameter is 1.2 mm.and the average diameter of apparently complete sections of the oolites is about 0.8 mm.

A few grains of quartz are present in the oolites. There is no indication that these have interfered in any way with the growth of the oolites. Adjacent oolites frequently interfere with each other. The contact is sharp and abrupt, and is marked by a very narrow band carrying a little clay material. The banding stops at the contact between oolites, so that, in the case of oolites which grew together at an early stage, the brown band may appear to be continuous about two or more centres. However, growth apparently has continued from the separate centres, and not from the compound oolite as a whole. This is shown by the formation of distinct crosses in the various parts, and by the continuity of the contact to the edge of the oolite. The largest number of interfering oolites observed was five.

Similar oolites have been described from England (Spencer, 1925).

LOWER ALBERTA FORMATION
Consolidated Clay Shale (Slide #3)

Megascopic: A fairly soft, orange brown rock, with abundant crystals of biotite. This material looks like a tuff.

Microscopic: This slide consists almost entirely of calcite and very fine grained slightly anisotropic material, with a few scattered grains of orthoclase, biotite and chlorite.

The composition is:

Detrital:	Authigenic:
Orthoclase	Calcite
Quartz	Pyrite
Biotite	Chlorite?
Zircon	
Plagioclase	
Devitrified glass	

Orthoclase is the most abundant clastic present. It occurs in grains averaging 0.2 mm. Some of it belongs to the variety sanidine. Plagioclase is rare. All the feldspars are fairly fresh, although calcite has penetrated along the cleavages in some cases.

Quartz is not abundant. Biotite is plentiful, in crystals up to 1 mm. in diameter. Zircon is quite abundant in small euhedral grains.

Much of the groundmass is composed of a very fine grained, almost isotropic material which probably represents devitrified glass. This material sometimes shows shapes characteristic of chards.

Calcite makes up a large part of the slide. It occurs throughout the groundmass, as large anhedral crystals up to 0.3 mm. and rarely in a spherulitic form. Pyrite is not abundant, but occurs in cubic crystals. A green material which is present in the groundmass, may be chlorite.

This rock is probably derived from a tuff.

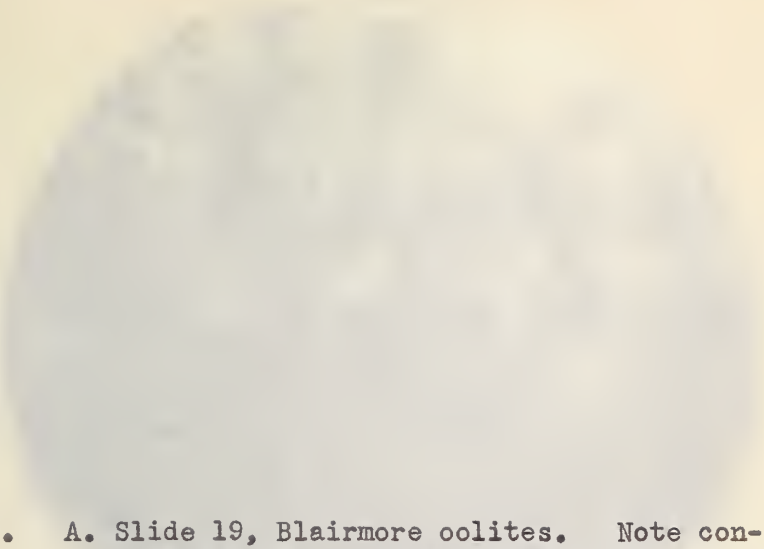
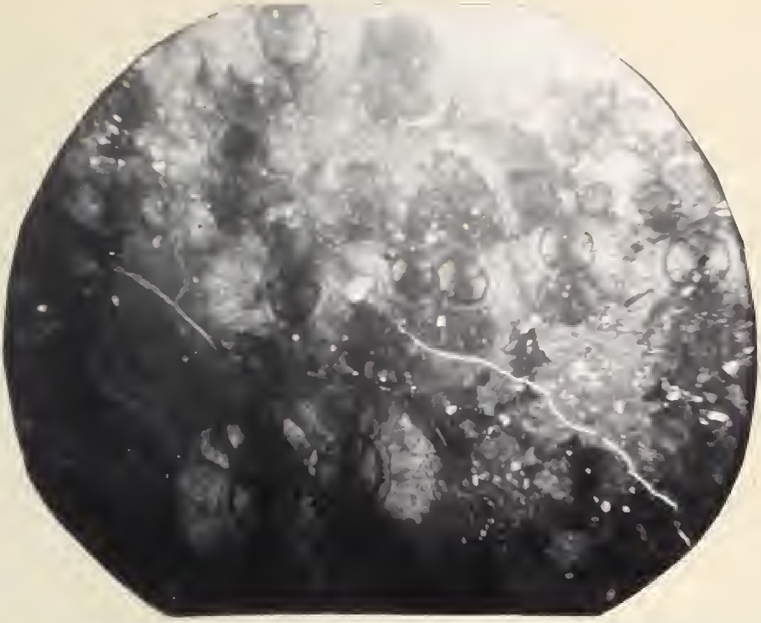


Plate XXII. A. Slide 19, Blairmore oolites. Note concentric banding, coarser crystals in outermost band, interference of adjacent oolites and relief brush across each oolite. x36

B. Immersion mount of residue after washing of white clay-shale from Lower Alberta formation. Largely kaolinite-like mineral. Striated grains, pinacoidal view. Non-striated grains, basal view. x64



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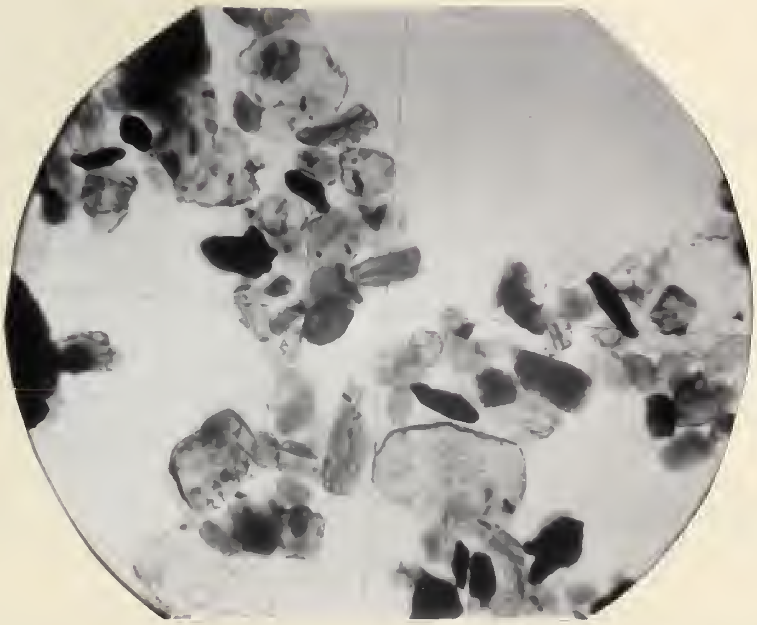

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BIBLIOGRAPHY

Allan, J. A. 1921 "Highwood coal basin" and "Sheep River coal basin", Research Council of Alberta, Report 2, pp. 40-50.

1926 "Available coal supply" (of Alberta), Research Council of Alberta, Report 16, pp. 40-44.

1932 "Mowitch and Rock Creeks: Gypsum", Research Council of Alberta, Report 27, pp. 27-29.

1933 "A new deposit of gypsum in the Rocky Mountains, Alberta," Trans. Can. Inst. Min. Met. vol. 36, pp. 619 - 635.

1945 "Coal Reserves", Alberta Government submission to the Royal Commission on the Coal Industry of Canada, Part D.

Ashley, G.H. 1918 "Cannel coal in the United States", U.S. Geol. Surv. Bull. 659.

Beach, H.H. 1943 "Moose Mountain and Morley map-areas, Alberta", Geol. Surv. Can. Memoir 236.

Bell, W.A. 194~~4~~5 "Use of some fossil floras in Canadian stratigraphy", Trans. Roy. Soc. Can. 3d ser., vol. 38 , sec. IV, pp. 1-14.

Brown, R.W. 1946 "Fossil plants and the Jurassic-Cretaceous boundary in Montana and Alberta". Bull. A.A.P.G. vol. 30 pp. 238-248.

Buckman, S.S. 1929 "Jurassic Ammonoidea" in "Mesozoic Paleontology of Blairmore Region, Alberta", Geol. Surv. Can. Mus. Bull. 58, pp. 1-27.

Cairns, D.D. 1908 "Moose Mountain district, Southern Alberta", Geol. Surv. Can., Pub. 968; 1914, 2nd ed., Memoir 61.

Clarke, F.W. 1924 "The data of geochemistry", U.S. Geol. Surv. Bull. 770.

Cobban, W.A. 1945 "Marine Jurassic formations of the Sweetgrass Arch, Montana", Bull. A.A.P.G. vol. 29, pp. 1 262-1304.

Dawson, G.M. 1886 "Preliminary report on the physical and geological features of that portion of the Rocky Mountains between latitudes 49° and 50°30'", Geol. Surv. Can. An. Report. New ser. vol. 1, 1885, part B.

Dawson, J.W. 1886 "On the Mesozoic floras of the Rocky Mountain region of Canada", Proc. & Trans. Roy. Soc. Can . vol. 3, sec. 4, pp. 1-22.

Dowling, D.B. 1914 "Coal fields of Manitoba, Saskatchewan, Alberta and eastern British Columbia", Geol. Surv. Can. Memoir 53.

Fox, F.G. 1942 "A Cretaceous grit bed horizon in the districts west and south from Turner Valley, Alberta", M.Sc. Thesis, Department of Geology, University of Alberta.

Geol. Surv. Can. 1924 Geological map, "Upper Elk and Upper Highwood Rivers, British Columbia and Alberta", Pub. 1980, scale, 1:250,000.

Hage, C.O. 1943 "Dyson Creek map-area, Alberta", Geol. Surv. Can. Paper 43-5.

Hume, G.S. 1930 "The Highwood-Jumpingpound anticline, with notes on Turner Valley, New Black Diamond, and Priddis Valley structures", Geol. Surv. Can. Sum. Rept. 1929 part B, pages 1-24.

1933 "Oil and gas in Western Canada", Geol. Surv. Can. Ec. Geol., Ser. No. 5 (second edition).

Jones, I.W. 1924 "Geology of the Kananaskis-Palliser map area, B.C. and Alta.", Stutchbury Research Prize Competition, Department of Geology, University of Alberta.

Lammers, E.C.H. 1939 "The origin and correlation of the Cloverly conglomerate", Jour. Geol. vol. 47, pp. 113-132.

Leach, W.W. 1903 "The Blairmore-Frank coal fields", Geol. Surv. Can. An. Rept. New Ser. vol. 15, part A, pp. 169-181.

1911 "Geology of Blairmore map area, Alberta," Geol. Surv. Can. Sum. Rept. 1911, pp. 192-200.

McConnell, R.G. 1887 "On the geological structure of a portion of the Rocky Mountains", Geol. Surv. Can. An. Rept. 1886, New. Ser. Vol. II, Part D.

Marshall, J.R. 1922 "Kananaskis Lakes-Palliser map area, British Columbia and Alberta", Geol. Surv. Can. Sum. Rept. 1921, part B, pp. 91-94.

MacKay, B.R. 1932 "The Mesozoic-Paleozoic contact and associated sediments, Crowsnest district, Alberta and British Columbia", Geol. Surv. Can. Sum. Rept. 1931, part B, pp. 1-25.

McLearn, F.H. 1929 "Contributions to the stratigraphy and palaeontology of Skidegate Inlet, Queen Charlotte Islands, B.C.", Geol. Surv. Can. Mus. Bull. 54, pp. 1-27.

1929a "Stratigraphic Palaeontology" in "Mesozoic Palaeontology of Blairmore Region, Alberta", Geol. Surv. Can. Mus. Bull. 58, pp. 80-107.

1932 "Problems of the Lower Cretaceous of the Canadian Interior", Trans. Roy. Soc. Can. 3rd ser., vol. 26, sec. IV, pp. 157-175.

1937 "Fossil zones of the Upper Cretaceous Alberta shale", Trans. Roy. Soc. Can. ser. 3, vol. 31, sec. IV, pp. 111-120.

1945 "Revision of the Lower Cretaceous of the western interior of Canada", Geol. Surv. Can. Paper 44-17, second edition.

McLearn, F.H. and Hume, G.S. 1927 "The stratigraphy and oil prospects of Alberta, Canada", Bull. A.A.P.G., vol. 11, pp. 237-260.

Reeside, J.B. Jr. 1923 "A new fauna from the Colorado group of southern Montana", U.S. Geol. Surv. Prof. Paper 132B.

Rose, B. 1919 "Northern part of Crowsnest coal field, Alberta", Geol. Surv. Can. Sum. Rept. 1918, part C, pp. 13-17.

1921 "Highwood coal area, Alberta", Geol. Surv. Can. Sum. Rept. 1919 part C, pp. 14-20.

Ross, C.S. and Kerr, P.F. 1931 "The kaolin minerals", U.S. Geol. Surv. Prof. Paper 165, pp. 151-176.

Rutherford, R.L. 1923 "Geology along Blackstone, Brazeau and Pembina rivers in the foothills belt, Alberta", Research Coun. Alta., Report 9.

1924 "Corrosion by saline waters", Trans. Roy. Soc. Can. 3rd Ser., vol. 18, sec. IV, pp. 31-37.

Schofield, S.J. 1923 "The geological record of the Cordillera in Canada", Trans. Roy. Soc. Can. 3rd ser. vol. 17, sec. IV, pp. 79-103.

Shimer, H.W. 1926 "Upper Paleozoic faunas of the Lake Minnewanka section, near Banff, Alberta", Geol. Surv. Can. Mus. Bull. 42, pp. 1-84.

Spencer, E. 1925 "On some occurrences of spherulitic siderite and other carbonates in sediments", Quart. Jour. Geol. Soc. London, Vol. 81, pp. 667-705.

Stansfield, E. and Lang, W.A. 1944 "Coals of Alberta, their occurrence, analysis and utilization", Research Council of Alta. Reprt 35.

Stewart, J.S. 1919 "Geology of the disturbed belt of southwestern Alberta", Geol. Surv. Can. Memoir 112.

Telfer, L. 1933 "Phosphate in the Canadian Rockies", Trans. Can. Inst. Min. Met. vol. 36, pp. 566-618.

Twenhofel, W.H. 1926 "Treatise on Sedimentation", Baltimore.

Tyrrell, J.B. 1886 "Report on a part of Northern Alberta", Geol. Nat. Hist. Soc. Can. Vol. II, Report E.

Wallace, R.C. 1917 "The corrosive action of certain brines in Manitoba" Jour. Geol. Vol. 25, pp. 459-466.

Warren, P.S. 1926 "Banff area, Alberta", Geol. Surv. Can. Mem. 153.

1932 "A new pelecypod fauna from the Fernie formation, Alberta", Trans. Roy. Soc. Can. ser. 3, vol. 26, sec. IV, pp. 1-36.

1934 "Present status of the Fernie shale, Alberta", Amer. Jour. Sci. 5th ser., vol. 27, pp. 56-70.

Warren, P.S. 1938 "The Blairmore conglomerate and associated sediments", Trans. Roy. Can. Inst. Vol. 22, part I pp. 7-20.

1945 "Triassic faunas in the Canadian Rockies", Amer. Jour. Sci. Vol. 243, pp. 480-491.

Warren, P.S. and Rutherford, R.L. 1928 "Fossil zones in the Colorado shale of Alberta", Amer. Jour. Sci. 5th ser. vol. 16, pp. 129-136.

Webb, J.B. and Hertlein, L.G. 1934 "Zones in Alberta shale ("Benton group") in the foothills of southwestern Alberta, Bull. A.A.P.G. vol. 18, pp. 1387-1416.

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